JOURNAL OF

METALS

APRIL 1960

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JOURNAL OF

METALS

Vol. 12, No. 4
April, 1960

COVER: Drawn by David Cain, this scene in an open-hearth shop is dedicated to the 43rd conference of the National Open Hearth Steel Committee and the Blast Furnace, Coke Oven, and Raw Materials Committee. Papers from these conferences, as well as other articles of interest to iron and steel metallurgists, are contained in this issue.

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WESTERN ADVERTISING REPRESENTATIVE: Dillenbeck-Galavan Inc., 266 S. Alexandria Ave., Los Angeles 4, Calif.

Address insertion orders and copy to: Advertising Department, JOURNAL OF METALS, 29 West 39th Street, New York 18, N. Y. Send plates to: JOURNAL OF METALS, C/O Lew A. Cummings Co., Inc., 215 Canal St., Manchester, N. H. Published the first day of each month by the American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., 29 West 39th Street, New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $10 per year for non-AIME members; $6 for AIME members, or $4 additional for members; only in combination with a subscription to "Mining Engineering" or "Journal of Petroleum Technology." Single copies, $1.50. Transactions of The Metallurgical Society of AIME, $5 additional to members, $20 to non-members, and $25 foreign . . . The AIME is not responsible for any statement made or opinions expressed in its publications . . . Copyright 1960 by the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. . . . Registered address, AIME New York . . . Indexed in Engineering Index, Industrial Arts Index, and Chemical Abstracts . . . Second class postage paid at New York, N. Y., and at Manchester, N. H. Numbers of copies in this issue, 12,100.

personnel

• These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the societies of Civil, Electrical, Chemical Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

• When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

—MEN AVAILABLE—

All those listed under "Men Available" have membership in AIME.

Metallurgical Engineer; B.S., M.S. Nineteen years administration, development, consulting to designers and engineers, technical service and publications. Steel industry, ferrous and nonferrous metal forming, welding, and material process magazine. Seeks new challenge in industry, publications, or technical society. M-225

Metallurgical Engineer; B.S. ChE. Twenty-two years experience in metalworking field; seven years market development and technical sales to steel mills, foundries, and reactive metal plants; 15 years plant metallurgist (ferrous and nonferrous) on heavy electrical equipment manufacturing. Prefer East Coast but other locations acceptable. M-226.

Research Metallurgist; Diploma in Chem Eng, Ph.D. in metallurgy, age 38. Three years experience chemical laboratories, one year teaching, two years academic research, and three years industrial research in ferrous and nonferrous process and physical metallurgy. Prefer East. M-227.

Mine or Mill Superintendent; EM Min, Met, age 40. Fifteen years experience on economic evaluation; organizing exploration programs; staffing and operating properties,; budgeting; financing; labor negotiations; consulting on fluorspar, uranium, and manganese; and lead-zinc mine and mill operations. $12,000 Prefer Calif. or other US location Se-992.

Mill Superintendent; age 51 (four years college-ore dressing). Many years experience as mill superintendent and consultant on silver, lead, copper, cobalt, tungsten, and iron. $9600. Prefer western US or any. Se-263.

Process or Physical Metallurgist; MetE, age 26. Two years as metallurgical engineer in quality control and heat treating in nonferrous sand castings foundry; one year operation of pilot plant for extraction in copper smelter. Two years instructor on fundamentals of electronics, Air Force. $7200. Prefer West, North, or Central US. Se-159.

Production or Management Engineer; MinE, age 41. Eighteen years experience in mining and mineral dressing in non-metallics—underground, open pit, all phases mineral dressing. Also experienced in exploration, research and development, and design and construction. Staff engineering background in costs, estimating and budgeting, and reports. Desire production or engineering management position. $12,000. Prefer West Coast but other locations acceptable. Se-1740.

Consultant; M.S. MetE (Australia), age 52. Very wide experience in all phases of copper smelting and refining, electric furnace melting of copper, powder metallurgy, and so on; also lead smelting and refining. $18,000. Prefer West or foreign. Se-1851.

Superintendent; ChE, age 43. Twenty-five years experience in nonferrous concentrating and hydrometallurgical operations, including duty as chief chemist, furnace superintendent, mill superintendent, spectrographer, surveyor and chemist-assayer. Salary open. Prefer West. Se-1619.

—POSITIONS OPEN—

Address replies for positions to the nearest local office of the Engineering Societies Personnel Service, Inc., *not* to the JOURNAL OF METALS. Offices are located at 29 E. Madison St., Chicago 1, Ill. . . . 57 Post St., San Francisco, Calif. . . . and 8 W. 40th St., New York 18, N. Y.

Metallurgical Sales Engineer. a) Sales Engineer with at least five years experience in metallurgical development or application. To sell and promote the use of refractory metals. Salary, $12,000 to $15,000. Location: New York City. b) Sales Engineer with sales development metallurgical experience in the petroleum, alloy iron and steel producers, and railroad industries. Salary $12,000 to $15,000. Location: Chicago. c) Sales Engineer with eight to ten years experience in the steel-producing industries. Salary, $12,000 to $15,000. Location: Pittsburgh. W8691.

Metallurgist; (solid state) for the development of high-temperature metals. For research organization. Salary, $12,000. Location: Mass. W-8673 (a).

Metallurgist, Physical Chemist, or Applied Physicist; with M.S. and X-ray diffraction experience. To assist in setting up and developing physical metallurgy experiments and prepare instructions covering experiments. Salary, $6000 to $8000. Location: Midwest. W8669C.

Research Metallurgist; graduate, with interest in applied physical metallurgical research and development. Will conduct programs related to high-temperature refractory metals, liquid metal corrosion, high strength of materials, or metal processing. New modern research center facilities available. Salary, $10,000 to $15,000. Location: Ohio. W8664.

Metallurgical Engineer with five to ten years experience, preferably with background in foundry or casting shop—ferrous or nonferrous. To concentrate on metallurgical area in R&D group of growing medium-sized manufacturer specializing in electric melting equipment. Will be concerned primarily with product development and application studies. Salary commensurate with experience and ability; pension plan and other employee benefits. Location: East. W8655.

Laboratory Engineer; metallurgical, nonmetallic, or inorganic chemical engineer to set up laboratory, select equipment and procedures of a chemical and physical laboratory for quality control and production research. Salary, open. Location: Tex. W8643S.

Metallurgical Engineer for staff position covering project design assignments and consultant responsibilities of hydro- and electro-metallurgical base metal plants. Salary, $12,000 to $15,000. Headquarters: New York, N. Y. W8630.

Metallurgical Engineers for work in fields of X-ray diffraction, electron microscopy, and metallurgy. Experience in these fields and Ph.D. desirable. Rank and salary open. Location: East. W8602 (b).

Plant Superintendent with some courses in metallurgy. Must have five years experience as foundry superintendent on centrifugal casting. Prefer experience as foreman or superintendent of machine shop or job shop working with large lathes and boring mills. Will report to divisional general manager and be responsible for supervision of foundry and machine shop of about 100. Basic responsibility for establishing and maintaining an effective plant organization and mutually satisfactory relations with the union. To produce quality nonferrous and cast-iron castings in the most economical manner possible and to machine them to customer specifications. Will also maintain the physical plant. Must be willing to live in small Midwest town. Employer will pay placement fee. C7953.

Research Engineer; M.S. ChE, MetE or Chem (not Mining) or B.S. with exceptionally strong research experience. Must be interested in applying knowledge to solution of industrial problems rather than to fundamental research. Department conducts applied research and development on new processes and major process improvements in fields of mineral beneficiation, hydrometallurgy, and pyrometallurgy. Salary commensurate with training and experience; liberal fringe benefits. Location: West. Sj-5074-R.

Consultant; metallurgist, with wide experience in copper smelting and refining and familiarity with operation and engineering in copper-producing areas throughout the world. Will provide technical direction for metallurgical plant and design construction, also technical assistance to operate smelters and refineries, plus handling development work for new methods. Must be top-notch with sound economic sense. Capable of contact work under variety of circumstances, including top management. Salary commensurate with education and experience. Headquarters: Mountain States. Sj-5071-R.

Plant Manager with supervisory and chemical production experience in metal salts. Salary, $10,000 to $12,000. Location: Md. W8666.

Engineers. a) Process Engineer, graduate ChE with five to ten years experience in supervising production of tungsten from ore. b) Graduate metallurgical engineer to develop process and controls in the fabrication of tungsten and molybdenum through powdered metallurgical process. Salary, open. Location: northern N. J. W8633.

Physical Metallurgist, for development of aluminum alloys and fabricating practices. Salary commensurate with education and experience. Location: Pacific Northwest. Sj-5021.

NEW BULLETIN

A new bi-weekly bulletin of "Engineers Available" is now being published by the Engineering Societies Personnel Service, Inc. Distributed free of charge, the bulletin contains synopses of the experience of engineers who have registered with the Service and are seeking a new position.

Any employer interested in receiving the bulletin should so advise E.S.P.S. at 8 W. 40th St., New York 18, N.Y., and your name will be placed on the mailing list. Any engineer who is registered with the Service or wishes to register is entitled to a 35-word notice in the bulletin. Write to the New York office for forms. Your qualifications will be brought to the attention of employers on our mailing list without revealing your identity.

It is planned to extend the publication to the midwestern and western offices in the near future.

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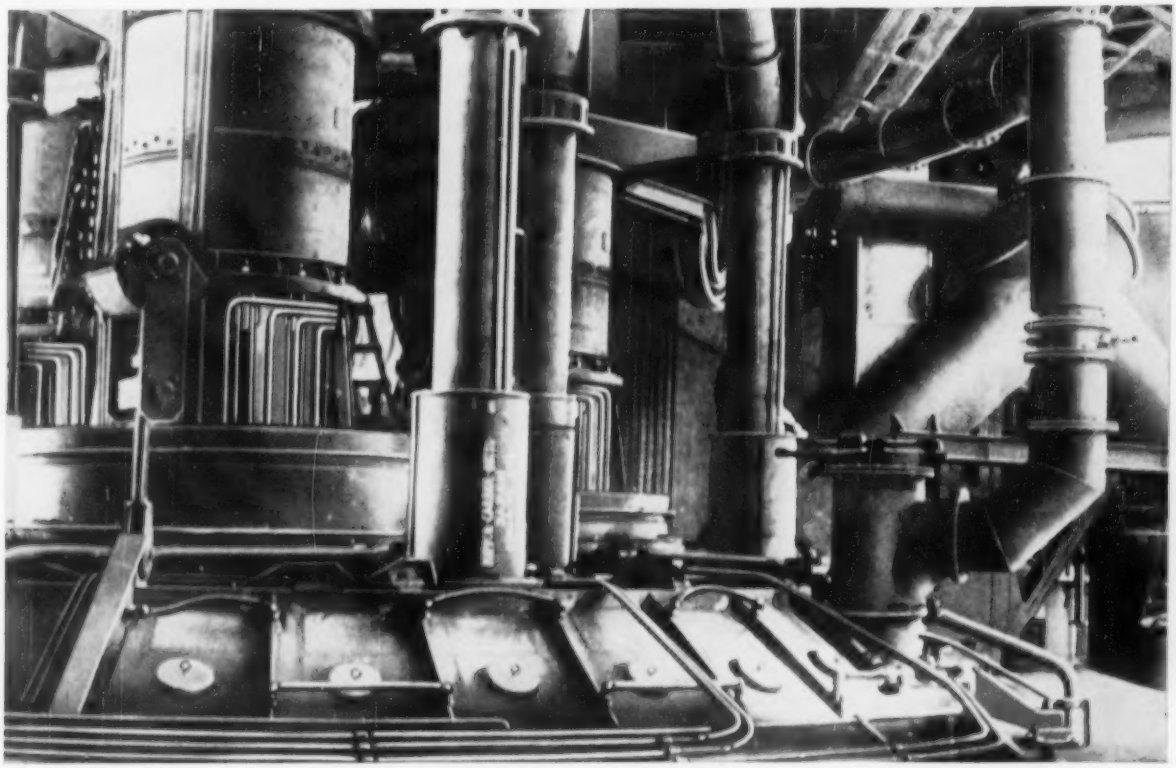

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U of C to Sponsor Summer Metals Course

A two-week course in metal processing and forming is being sponsored by the Department of Engineering and the Engineering Extension division of the University of California, Los Angeles. The dates will be July 18-29. The purpose of the course is to examine some of the recent advances in the technology and theory of metal forming.

The course content will include the principles of forming procedures and their practical applications . . . criteria of failure by plastic and elastic instability (necking and buckling) . . . plastic flow processes . . . boundary and surface conditions . . . high strain-rate forming . . . spinning, shear, and creep forming . . . lubrication . . . and economics. Presentation of the material will be through lectures, problem solving sessions, and round table discussions.

Fee for the course is $150. Two units of professional credit are granted upon completion.

For more information, contact: *Engineering Extension, Rm. 6266, Engineering Bldg. Unit II, University of California, Los Angeles 24, Calif.*

ASEE Annual Meeting At Purdue June 20-24

The American Society for Engineering Education will hold its 68th annual convention on the Purdue University campus June 20-24. Some 45 general sessions and special conferences will take place during the week. The impact of new technologies . . . high school preparation for college . . . and a workshop on solid state electronics are among the topics to be discussed.

For reservations and complete program, address *Prof. Mark Roberts, Engineering Administration, Purdue University, Lafayette, Ind.*

ISI to Host Symposia On Making Wide Strip

The 91st Annual General Meeting of The Iron and Steel Institute will be held in London May 3-5. Future Requirements of the Vehicle and Tinplate Industries . . . Steelmaking for Wide Strip . . . Hot Rolling of Wide Strip . . . Cold Rolling and Heat Treatment of Wide Strip . . . Coatings . . . and Steelmaking in Electric Arc Furnaces will be the session titles.

Some of the papers to be presented include *Oxygen Steelmaking for Flat-Rolled Products*, by R. W. Evans, Steel Co. of Wales Ltd. . . . *Open-Hearth Steelmaking Practice for Flat-Rolled Products*, by S. J. Dougherty, Weirton Steel Co., and R. Duffett, Great Lakes Steel Corp. . . . *Production of Steel with Intensive Use of Oxygen in the Open-Hearth Melting Shop at Cornigliano*, by M. Foresi and G. Massobrio, Cornigliana S. p. A. . . . and *Quality Control of Wide Strip Mill Products*, by J. H. Van der Veen, Royal Netherlands Blast Furnaces and Steel Works Ltd.

Also, *Metallurgical Principles and Practice in the Manufacture of Cold-Reduced Tinplate*, by W. J. S. Roberts, Steel Co. of Wales Ltd. . . . *The Rolling of Very Thin Tinplate*, by M. D. Stone, United Engineering and Foundry Co. . . . *Some Engineering and Operating Problems in the Conversion of a Tandem Cold-Reduction Mill to Higher Speed*, by W. H. Corlett, S. A. Lewitt, and S. Gray, John Summers & Sons Ltd. . . . *Short-Time Annealing of Capped, Rimmed, and Semi-Killed Wide Strip*, by P. N. Richards, John Lysaght Pty., Ltd. (Australia) . . . and *Annealing of Cold-Reduced Sheet and Coil*, by H. H. Ascough, Steel Co. of Wales Ltd.

For more information, address: *K. Headlam-Morley, Secretary, The Iron and Steel Institute, 4 Grosvenor Gardens, London S. W. 1.*

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▼**Personals:** Please list below your former company and title and your new title and company (or new work) for use in JOURNAL OF METALS. (Copy deadline for personals items is six weeks before date of issue.)

Former Company _____

Former Title _____ Length of Time There _____

New Company _____

New Company Address _____ Date of Change _____

New Title _____

Any recent activity that would be of interest to members:

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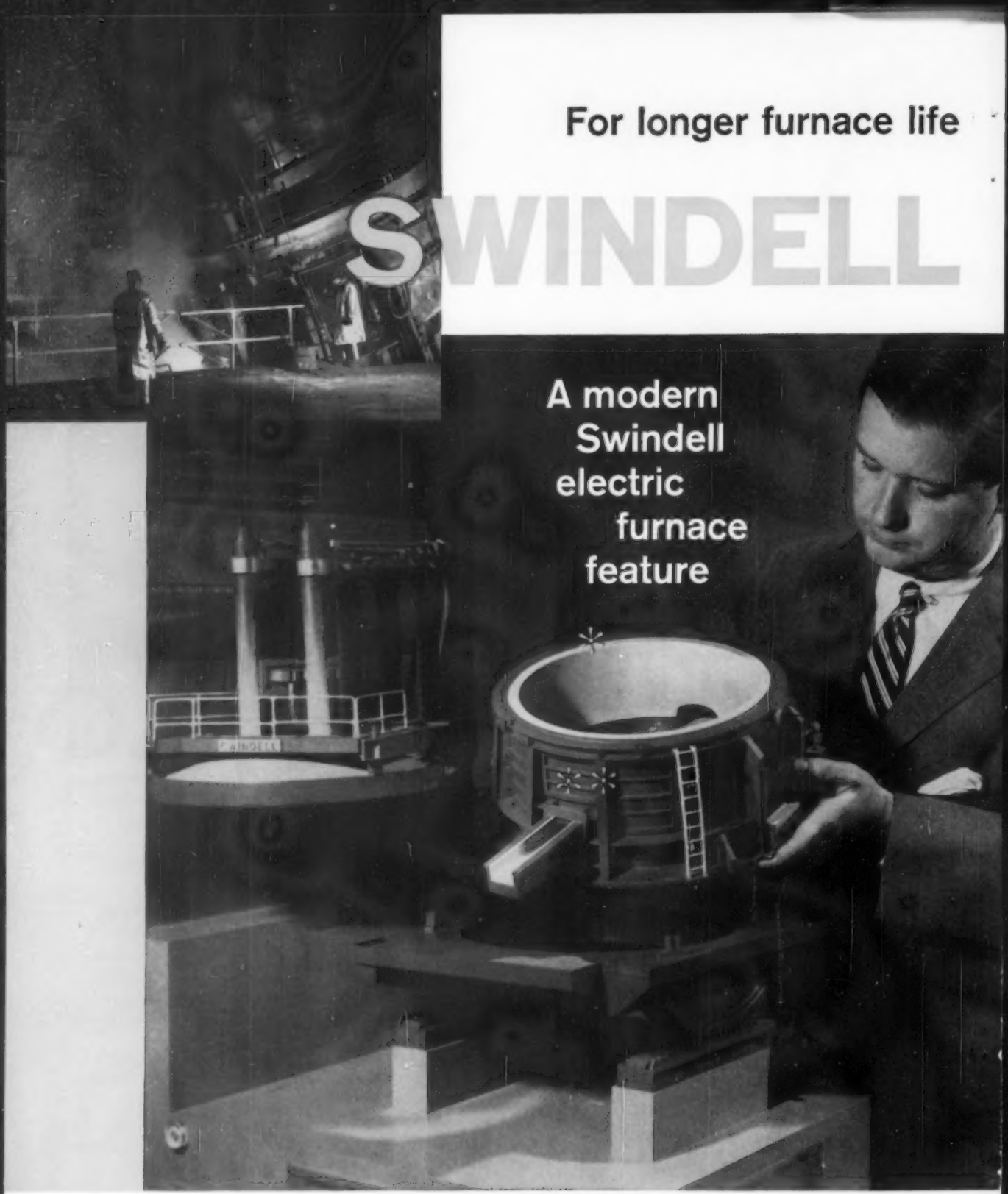

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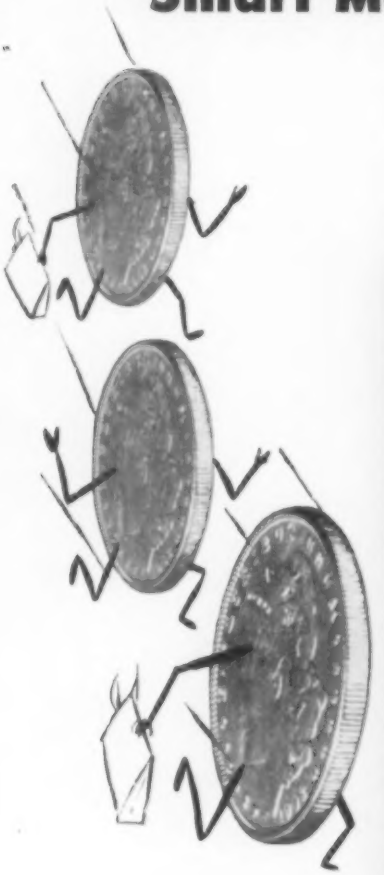

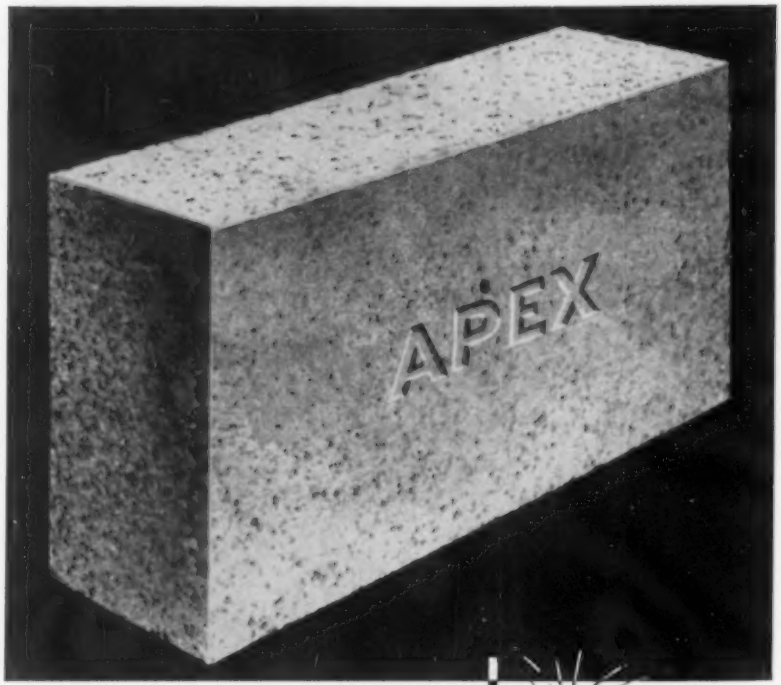

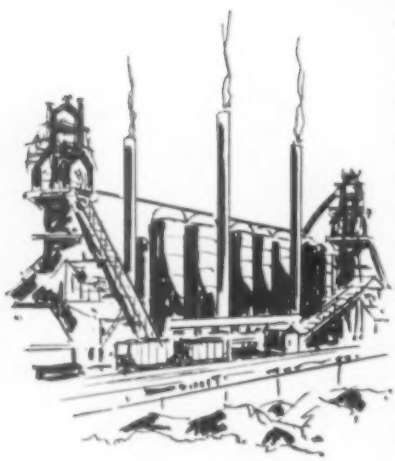

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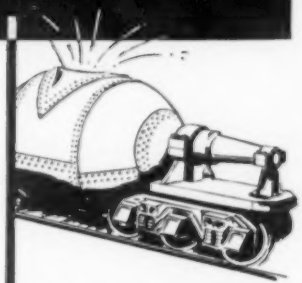

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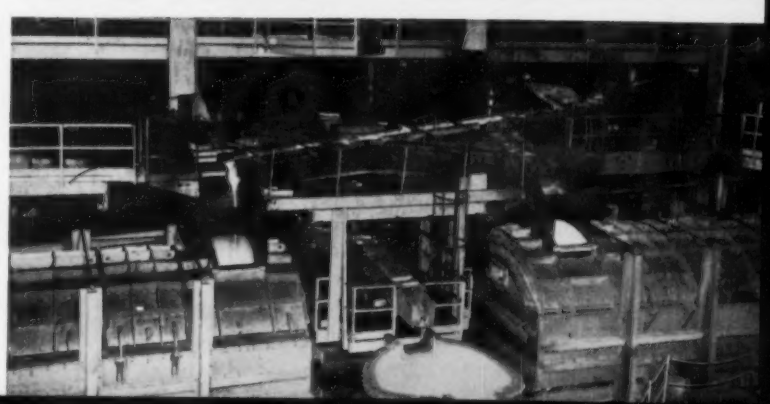
From the complete range of types and classes of Harbison-Walker refractories may be selected those which meet the specific and varied requirements of basic oxygen furnaces, hot metal mixers and other types of furnaces. At the Riverdale, Illinois, plant of Acme Steel Company these refractories are proved to have the qualities needed for long and efficient service.

Harbison-Walker has maintained leadership in the refractories industry through continuous research, product development, modernization and expansion of production facilities and an exceedingly effective quality control program.

(*Above, right*) One of a pair of Acme's 30 to 50-ton oxygen furnaces. The Harbison-Walker linings, consisting of H-W MAGNESITE and H-W 17-56 brick and H-W OXIMIX monolithic refractory, holding excellent records, continue to give splendid service.

(*Below*) Two 200-ton hot metal cradle mixers. The widely used H-W brands—H-W PERIKLASE, WALSH T, VARNON BF, MAGNEX H and ANCHOR DASH—have been selected for both linings, based on highly satisfactory performance in this application.



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Payoff in portable photons

Samarium-145, Samarium-153, Gadolinium-153.
Scientists at the General Motors Research Laboratories began three years ago to measure and re-evaluate the nuclear characteristics of these rare earth isotopes – their half-lives, photon emissions, thermal neutron cross sections.

Conclusion: the radioisotopes had attractive possibilities in industrial and medical radiography, emitting almost pure gamma rays or X-rays (photons) in the low energy range of 30 to 100 kev.

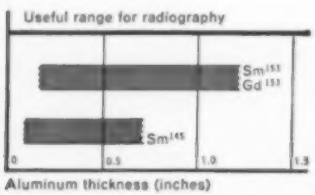
The transition from research to hardware came through two key developments. First, cermet pellets were fabricated using only a few milligrams of the rare earth oxides. Then the irradiated pellets were packaged in special bullet-size holders.

The resulting small, sealed radiographic sources are now being field and laboratory tested. Two excellent applications: "inside-out" checks of hollow shapes inaccessible to X-ray tubes, and radiography of thin steel sections and low density materials such as aluminum or human bone. For example, a recent medical milestone was a chest radiograph of a living person made with a Sm^{153} source. The portable exposure unit to shield the source weighed only 18 pounds.

This isotope radiography program is but one example of the work underway in GM Research's modern isotope laboratory – work that means, through science, "more and better things for more people."

General Motors Research Laboratories

Warren, Michigan



Aluminum thickness (inches)

Sm^{153} exposure unit.

Low-grade iron ore probed

The feasibility of commercially processing Minnesota's' semi-taconite is under investigation by two steel producers.

The M. A. Hanna Mining Co., is planning a $2 million pilot plant for Cooley, Minn. in the western portion of the Mesabi range. The Oliver Iron Mining div. of U. S. Steel Corp., meanwhile, will build a pilot facility nearby at Coleraine.

Both plants will experiment with roasting processes for changing the low-grade ore to a magnetic form. U. S. Steel plans to use propane as a fuel at first, but might also try natural gas, lignite, and coal.

Hanna officials indicate that the favorable tax treatment toward semi-taconite granted by the Minnesota state legislature in 1959 had bearing on their pilot-plant plans. Similar tax leniency was granted to taconite in 1941.

French Al capacity up

Two aluminum plants are making use of the Pyrenees' natural gas deposits. One is the Lannemezan plant of Ugine, already in operation at a rated capacity of 23,000 metric tons annually. The recently-inaugurated 240-cell Noguères plant of Pechiney is rated at 56,000 metric tons annually. Combined, the two plants increase France's aluminum capacity by 50 pct. Both plants will be powered by a new 125,000-kw gas—powered generating station at Artix.

While the Noguères plant's 100,000-amp cells are analogous to those at St. Jean-de-Maurienne (See JOURNAL OF METALS, January 1958, p. 38), they include important refinements. Processing of one metric ton of aluminum (from arrival of alumina in the electrolysis hall until transport of the metal to the foundry) requires 8 hr at St. Jean-de-Maurienne, while at Noguères it takes about 4.5 hr.

New thermocouple made

A new expendable-type immersion thermocouple for measuring molten metal temperatures has been developed by the Instruments and Systems div., Engelhard Industries Inc.

The thermocouple consists of a ceramic base which is a mounting for the noble metal thermocouple wires. A firmly-anchored, transparent, fused silica tube protects the thermocouple wires and is, in turn, protected from slag and floating solids by a special metal cap. The cap absorbs the physical shock of immersion and melts away immediately after it has plunged beneath the slag. The thermocouple is designed for use in both open-hearth and electric furnaces, and may be used with other metals besides steel.

'Biggest' continuous caster

A twin-strand continuous casting unit being installed at the Steel Co. of Wales Ltd., is said to be the largest of its type outside the Soviet Union. It will produce basic-bessemer steel slabs 27 x 6 in. to 48 x 9 in. and up to 21 ft long. The BISRA continuous casting process will be used in the unit. The plant will be supplied by Continuous Casting Co., Ltd., Licensee for the BISRA process.

Uranium monocarbide hailed

The *leading candidate* for the reactor fuel of the future is uranium monocarbide, so say Battelle Memorial Institute Researchers Frank A. Rough and R. F. Dickerson. Shortcomings in metal and uranium dioxide as fuel materials has led to intensified study of uranium monocarbide. Among the findings are:

1) Uranium monocarbide possesses heat conductivity that is almost identical with that of unalloyed uranium at low temperatures, and about two-thirds that of uranium at temperatures around 700°C. With a melting point of about 2315°C, uranium monocarbide has the advantage of being able to withstand nearly twice the amount of heat that uranium can take. Its melting point is only 400°C below that of uranium dioxide.

2) For equivalent amounts of material, there is substantially more uranium fuel in uranium dioxide. This is an important consideration in the design of compact nuclear reactors.

3) While there are still serious gaps in information needed to evaluate uranium monocarbide's ability to withstand radiation damage, there is reason to believe that it will be as serviceable under operating conditions as is uranium dioxide. Research now in progress at Battelle should do much to clear up this point.

4) Uranium monocarbide can be processed into fuel elements by several methods. The fact that casting is a low-cost fabriction technique and uranium monocarbide can be cast speaks well for this material, which behaves in some ways like a metal, and in other ways like a non-metallic material.

However, Rough and Dickerson point out that uranium monocarbide also has some limitations. It has no resistance to corrosion by water, so, it is not suitable as a fuel for water-cooled reactors, unless some means is found to improve this property. Powders of uranium monocarbide are also highly flammable, and must be handled in a special atmosphere during fabrication. Finally, there is the possibility that other handling problems might develop in the chemical reprocessing of spent fuel.

African iron deposit

Development of high-grade iron ore deposits in the Islamic Republic of Mauritania in northwest Africa was recently given impetus with a World Bank loan of $66 million. Recipient of the loan is the Societe Anonyme des Mines de Fer de Mauritanie (Miferma). Miferma owns less than half of the shares in the company, the remainder being held by French, German, British, and Italian iron ore consumers.

The iron ore deposits are located in a low mountain range known as the Kedia D'Idjil, which rises above the Sahara plain at Fort Gouraud.

Open pit reserves with an average shipping grade of 63 pct Fe are estimated at 115 million tons. The ore will be mined by conventional open-pit methods, and shipped after crushing.

Beginning in 1964, a new railway will take trains—capable of carrying 10,000 tons of ore in a single trip— to Port Etienne on the Atlantic Coast, 415 mi away. Output will be some 4 million tons per year, later expected to be 6 million.

REPORTER

REPORTER

Lithium uses studied

The use of lithium as a coolant for ballistic bodies was discussed by H. K. Hebeler, Boeing Aircraft Co., during the recent meeting of the American Astronautical Society. He pointed out the potential of a lithium-cooled nose cone . . . availability and cost of lithium . . . and test objectives. He indicated that tests were promising and that this lightest of all metals might possibly extend the current boundaries of supersonic flight. One drawback is lithium's reactivity and corrosive nature.

In another paper, Flagg, McQueen, and Trent of Aerojet-General Corp. discussed nuclear rocket engines for space propulsion. Of prime importance is shielding material for the atomic engine, they point out. Lithium, lead, boron, tungsten, iron, and uranium 238 shield metals have been considered.

Chrysler makes own aluminum

Chrysler Corp. has become the automotive industry's first producer of its own aluminum. The Corp., which uses more aluminum per car than any other US auto producer, has taken over full operating control of one of Canada's six primary aluminum smelters—Beauharnois works of the Aluminum Co. of Canada. The St. Lawrence Seaway works has a rated capacity of 38,000 tons of primary aluminum ingot annually. Chryslum Ltd., a company jointly owned by Chrysler and Alcan, will operate the smelter.

The popularity of Chrysler's Valiant . . . with nearly 80 lb of aluminum in each one . . . is the basis for the Corp.'s new acquisition. The Chrysler line of cars now uses aluminum in pistons, oil and water pump components, clutch housings, transmissions, and as trim in grilles and window frames. Aluminum engines or motor blocks in 1961 is also a possibility, yet unconfirmed.

Natural gas for ironmaking

Abundant supplies of natural gas from the Lacq deposit in the Pyrenees of southwestern France are being used to fire blast furnace No. 3 of the Bouceau plant of the Forges de l'Adour. During the first 10 days of experimental operations only the fuel in the charge was altered; output of pig iron increased by 15 pct. With modified burden, the second 10 days showed a 27 pct increased output.

At this same plant, installation of a low-shaft electric furnace is being considered. It will use recent patents and the latest techniques in the production of metal from iron ores of the Ouenza mines in Algeria. Results of these tests will have an important bearing on the type of plant to be constructed at Bône in Algeria.

Zn-Ti-Cu alloy gets attention

Hydro T-metal is the name of the alloy given a resurgence of interest through marketing by Hydrometals Inc. It is a zinc-base alloy with titanium and copper additions. Its properties are easy formability, good corrosion resistance, and solderability. It also has desirable electrical properties. The alloy is said to have cost advantages over aluminum, copper, and stainless steel.

Actually an old discovery which was never exploited, the alloy is now gaining attention in the automotive industry and among the users of copper water tubing.

Foote plans new facility

A new electrolytic manganese facility is in the offing for Foote Mineral Co. with the recent purchase of a 670-acre tract near New Johnsonville, Tenn. Gordon H. Chambers, chairman of the board at Foote Mineral, states that the proposed plant will be the most modern in the world.

The Company's Knoxville, Tenn., plant is now on stream again after expansion of its electrolytic manganese facilities, according to recent information.

Largest consumable electrode

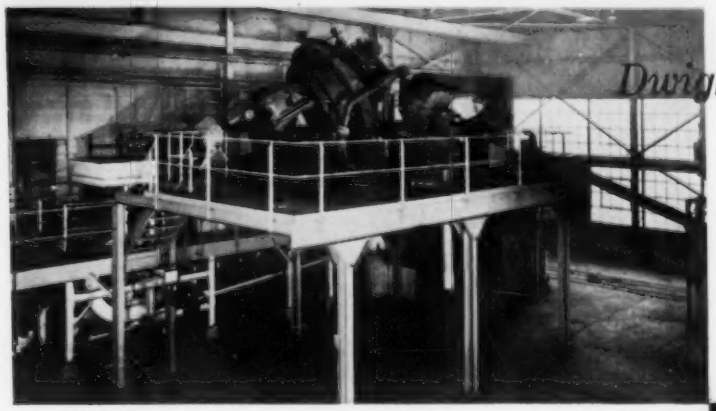
The largest vacuum-melting furnace in the world will be built at Allegheny Ludlum Steel Corp.'s Watervliet, N. Y., works. The consumable electrode vacuum-melting furnace is being designed to produce ingots 50 in. in diam and 40,000 lb in weight. With some modification of auxiliary facilities, even larger ingots are conceived. The largest commercially-produced vacuum-melted steel ingots today weigh less than 20,000 lb.

The Lectromelt div. of McGraw-Edison Co. is building the furnace. When completed, it will be the 11th consumable electrode furnace in commercial production at Allegheny Ludlum.

Make Pt-coated anode

Coating titanium with 0.0001 in. of platinum makes it act like a solid platinum anode, so finds the Crucible Steel Co. of America. Demonstration of this phenomenon was made at the Corrosion Show in Dallas, Tex., during the March meeting of the National Association of Corrosion Engineers.

Crucible believes that this discovery will prove valuable in cathodic protection, electroplating, and other electrochemical processes. They expect the anode to find large-scale use in the chlorine-caustic industry because it provides a maintenance-free cell.



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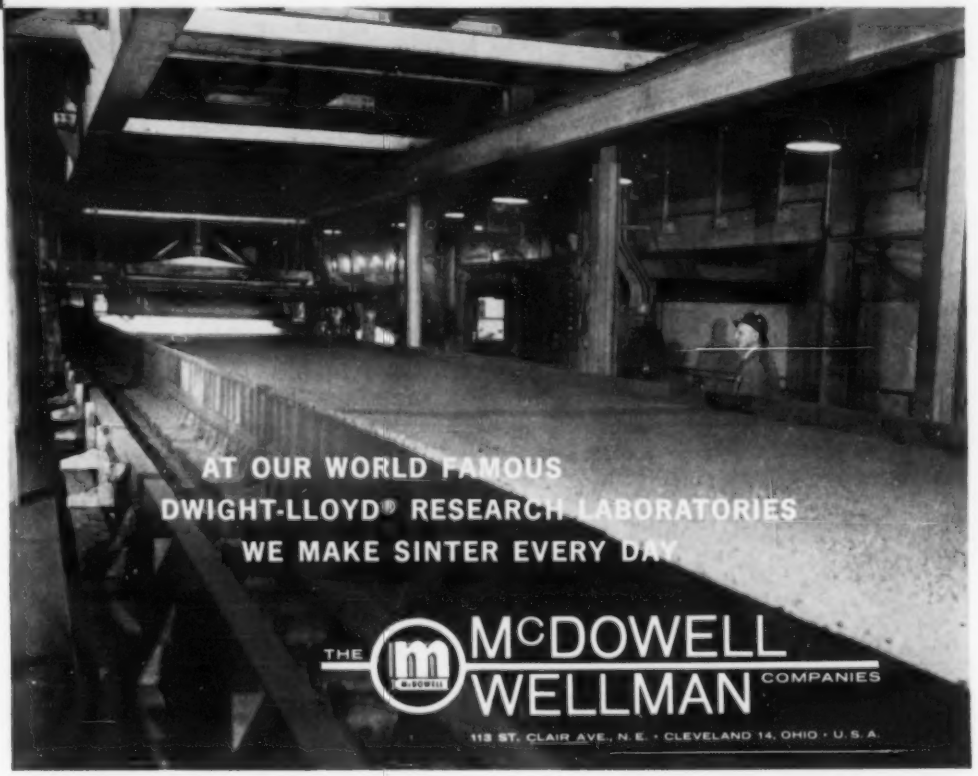
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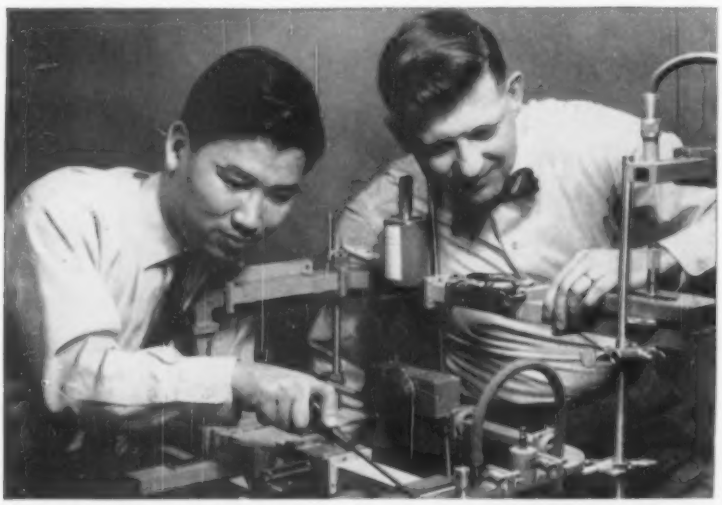
THE IDEA THAT GREW FOR 100 YEARS



At Bell Laboratories, M. Uenohara (left) adjusts his reactance amplifier, assisted by A. E. Bakanowski, who helped develop first suitable diode. Extremely low "noise" is achieved when certain diodes are cooled in liquid nitrogen.

First practical diode for amplifier, shown here held by tweezers, was jointly developed by A. E. Bakanowski and A. Uhlir.

How basic scientific ideas develop in the light of expanding knowledge is strikingly illustrated by the development of Bell Laboratories' new "parametric" or "reactance" amplifier.

Over 100 years ago, scientists experimenting with vibrating strings observed that vibrations could be amplified by giving them a push at strategic moments, using properly synchronized tuning forks. This is done in much the same way a child on a swing "pumps" in new energy by shifting his center of gravity in step with his motion.

At the turn of the century, scientists theorized that *electrical* vibrations, too, could be amplified by synchronously varying the *reactance* of an inductor or capacitor. Later amplifiers were made to work on this principle but none at microwave frequencies.

Then came the middle 50's. Bell Telephone Laboratories scientists, by applying their new transistor technology, developed semiconductor diodes of greatly improved capabilities. They determined theoretically *how* the electrical capacitance of these new diodes could be utilized to amplify at *microwave* frequencies. They created a new microwave amplifier with far less "noise" than conventional amplifiers.

The new reactance amplifier has a busy future in the battle with "noise." At present, it is being developed for applications in tropospheric transmission and radar. But it has many other possible applications, as well. It can be used, for instance, in the reception of signals reflected from satellites. It is still another example of the continuing efforts to improve your Bell System communications.

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The most rational exposition of fatigue of metals to be found in one book. The editors have sought the leading authority for each subject and put the key information into print. Critically selected bibliographies are provided, and the introduction includes a guide to fatigue literature, for those not thoroughly familiar with the field. The book presents a coordinated advanced treatment, by men who are experts, writing on their own specialties. Much of the subject matter is new.

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By Gilbert S. Schaller, University of Washington. 682 pages, $9.50.

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By Max Hansen, Metallgesellschaft A. G., Frankfurt-Main, Germany; in cooperation with Kurt Anderko, Metallgesellschaft A. G., Frankfurt-Main, Germany. *McGraw-Hill Metallurgy and Metallurgical Engineering Series.* Second Edition. 1305 pages, $35.00.

This revision and translation of the German work provides a source of reliable data concerning the constitution of binary alloy systems (phase diagrams) and the crystal structure of metallic phases. Widely scattered information in the world's metallurgical literature is analyzed and critically evaluated.

PHYSICAL METALLURGY

By C. Ernest Birchenall, Princeton University. 323 pages, $8.50.

The science of metals has taken enormous strides in the past few decades. In this book, the author takes cognizance of the new concepts, theories and experiments in order to produce an elementary text that "reflects in some measure the progress of recent years, the ferment and vitality of the field at present." To provide a sound underlying framework, the book has a strong scientific approach, at the expense of the engineering aspects. This exposition of fundamentals help to emphasize the unity underlying all aspects of the subject. In this respect the book departs significantly from all the other physical metallurgy texts and represents the long-awaited and much-needed approach to the subject.

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Physical Metallurgy, by Bruce Chalmers, *John Wiley & Sons, Inc.* 468 pp., $12.50, 1959—This text is the first to develop the subject of physical metallurgy in terms of atomic processes and interactions. The book's underlying theme is that the behavior of a metal is determined by its properties and environment . . . that the properties are determined by the structure of the metal . . . and that the structure, in turn, is determined by the chemical composition and history of the material. Since 1953, the author has been Gordon McKay professor of metallurgy, Harvard University. Dr. Chalmers is also editor of *Acta Metallurgica* and *Progress in Metal Physics.*

Advisory Editor for the Wiley Series on Science and Technology of Materials is J. H. Hollomon. •

How to Design and Buy Investment Castings, edited by R. H. Herrmann, *Investment Casting Institute,* 176 pp., $3.95, 1959—The book is divided into seven areas: advantages of the investment casting process . . . basic production techniques . . . choice of alloys . . . vacuum metallurgy . . . determining quality of cast parts . . . designing for investment castings . . and how to buy investment castings. The book also includes standards for design tolerances, and standards for inspection and surface finish. It includes a comprehensive index and special appendix covering investment casting terminology. •

British and Foreign Specifications for Steel Castings, Pt. I, *The British Steel Castings Research Association,* 48 pp., $7.50, 1959—Specifications for Austria, Belgium, France, Germany, Great Britain, Sweden, Switzerland, and the US are included in the steel castings manual. •

Tantalum and Niobium (Vol. VI of Metallurgy of the Rarer Metals), by G. L. Miller, *Academic Press, Inc.,* 767 pp., $21, 1959—This comprehensive volume includes all available chemical and metallurgical information on the forenamed metals. It incorporates such areas as: history and occurrence . . . consumption and uses . . . extraction . . . separation . . . production . . . consolidation . . . fabrication . . . physical and structural properties . . . mechanical properties . . . corrosion . . . binary alloy systems . . . and compounds. •

Internal Stresses and Fatigue in Metals, edited by G. M. Rassweiler and W. L. Grube, *Elsevier Publishing Co.,* 451 pp., $11, 1959—This work constitutes the proceedings of the Symposium on Internal Stresses and Fatigue in Metals, held at the General Motors Research Laboratories in 1958. The book's arrangement follows the Symposium program, first introducing internal stresses and then considering lattice strains and defects before progressing to studies of fatigue and its relation to stresses. The Symposium's purpose was to consider and interrelate the phenomena of internal stresses and fatigue metals—from both the atomistic approach of the solid state physicist, and the phenomenological approach used by the engineer in the design of cyclically-stressed components. •

Structure and Properties of Thin Films, edited by C. A. Neugebauer, J. B. Newkirk, and D. A. Vermilyea, *John Wiley & Sons, Inc.,* 561 pp., $15, 1959—This book records the complete proceedings of an international conference on thin films held last September. Their formation, mechanical, electrical, and magnetic properties . . . chemical interactions at surfaces . . . plus a panel discussion on the theory of surfaces are treated between the covers in a total of 43 papers. •

Precipitation Processes in Steels (1959), Special Report No. 64, by the *Iron and Steel Institute,* 322 pp., approx. $12—The 16 papers and five "discussion papers" which comprise this volume result from a July 1958 conference organized by the University of Sheffield's Dept. of Metallurgy. The papers are grouped under four categories: precipitation in ferritic steels . . . precipitation in austenitic steels . . . intergranular fracture in steels . . . and precipitation during creep. •

Engineering Manufacturing Methods, 2nd Edition, by Gilbert S. Schaller, *McGraw-Hill Book Co., Inc.,* 682 pp., $9.50, 1959—This edition has been thoroughly revised and a wealth of new information included. The introductory chapter includes new information on nucleonics and cybernetics. The latest techniques in molding and automation are also described in detail, and new ideas in vacuum melting and metal de-gassing are explained. Most illustrations and all end-of-chapter problems are new. •

Technical Editing, edited by B. H. Weil, *Reinhold Publishing Corp.,* 278 pp., $5.75, 1958—This book can prove valuable to the proceedings volume editor and to the aspiring author alike . . . as guide to the editor, and solace to the author who sometimes feels that his masterpiece has been done an injustice. It explains the responsibilities of author and editor

(Continued on page 270)

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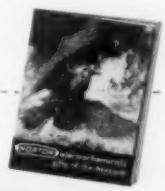

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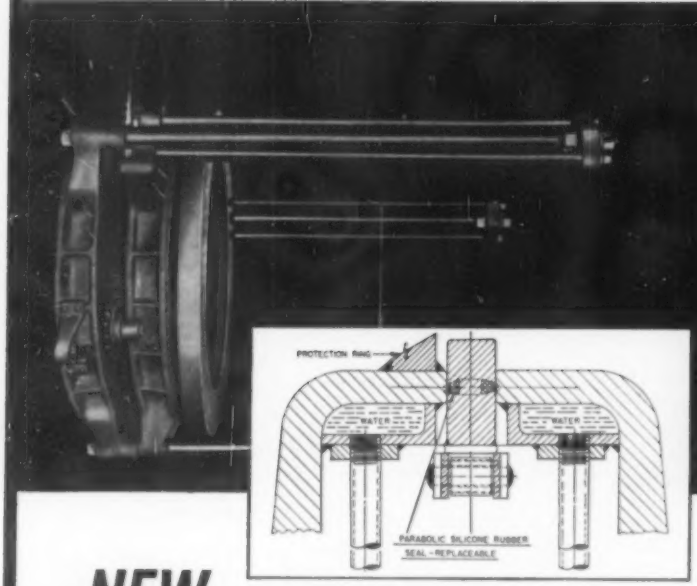

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BOOKS

(Continued from page 269)

alike in chronicling policies in force at different levels of the publication field.

The book is largely composed of papers presented at a Symposium on Technical Editing, held in conjunction with the American Chemical Society in 1957. The fact that each article constitutes a separate chapter in the 19-chapter book indicates the variety of its contents. Included are: Psychological, Educational, and Professional Aspects of Technical Editing . . . Editing Technical Reports . . . Internal Editing of Technical Papers and Articles . . . Editing Organization-Sponsored Magazines and Newsletters . . . Editing from the Patent Standpoint . . . Editing and Publishing Technical Abstracts for Internal Use . . . Training the Internal Technical Editor . . . Editing of Technical-Society Journals: The Editor's Viewpoint . . . Technical Editing: The Reviewer's Viewpoint . . . Editing the Technical Business Magazine . . . Editing Technical News Releases . . . Publisher Editing of Technical Books . . . Editing Technical-Equipment Manuals . . . Editing Slides and Other Graphic Aids . . . Editing Illustrations for Technical Reports and Papers . . . Editing Tabular Data . . . Editing Know-How—Techniques and Tools . . . Editing Translations . . . and Other Aspects.

Any criticism leveled would be on the grounds that it is more theoretical than applied. However, there is enough meat to bolster the knowledge of the practicing editor and many choice morsels for the uninitiated. •

General Chemistry, by Roland M. Whittaker, *Chemical Publishing Co. Inc.*, 752 pp., $12.50, 1959—This text is designed as both an introduction to the subject and as a refresher to those who have not kept up with activities in chemistry. The newest theories, basic applications, and technology of chemistry are developed systematically. An attempt is also made to relate chemistry to economics and world problems. The author, professor of chemistry, Queens College (N.Y.), has used the manuscript in teaching courses to chemistry teachers in National Science Foundation Institutes. Contents include: Introductory Concepts . . . Symbols, Formulas, Equations . . . Oxygen . . . Hydrogen . . . Water . . . Atmosphere . . . Atomic Structure . . . Nuclear Changes . . . Extranuclear Change . . . Three States of Matter . . . Molecular and Atomic Weights . . . Dispersed Condition . . . Electrolytic Dissociation and Ionization . . . Valence State and Oxidation-Reduction . . . Principles of Chemical Equilibrium . . . Ionic Equilibria . . . Periodic Groups I to VIII . . . Transition Elements . . .

(Continued on page 288)

education

Films

► Local sections and student chapters are eligible to receive a host of films on the metallurgical industry by simply contacting Modern Talking Picture Service, Inc.

The Service has just issued a revised edition of its Business and Professional Film Catalog, which lists at least 14 films of possible interest to metallurgists. All the films are 16 mm-sound.

Die Casting—How Else Would You Make It? is a 35 min color film made available by the American Zinc Institute. Sequences from actual production show the kinds of problems die casting can handle. Illustrated are the uses of zinc, aluminum, magnesium, and brass.

More Than Just Steel tells the story of special-purpose steels, such as electrical, thin-gage, asbestos-bonded, and stainless steels. The Armco Steel Corp. produced film is in color and runs 20 min.

Space, Time, and Steel is another Armco product. It depicts the use of steel in construction, and shows how units are built, packaged with fastners and hardware, and shipped to construction sites. The film runs 24 min and is in color.

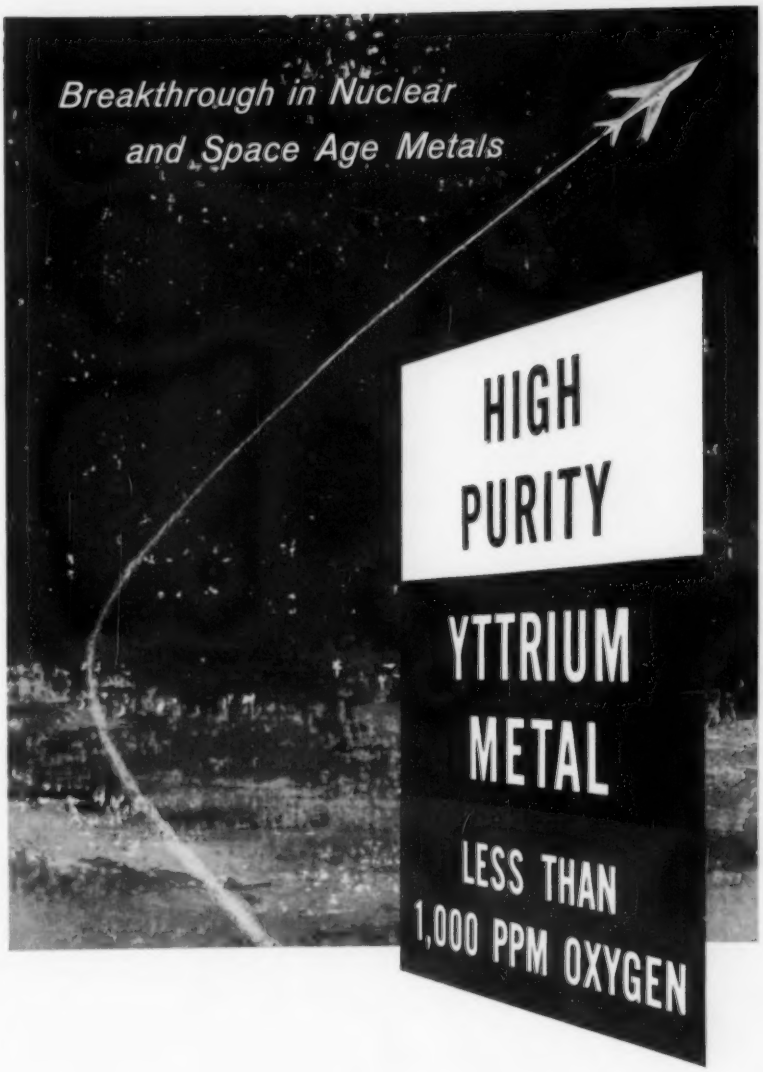
Bethlehem Steel Co. also has two pertinent films to offer. One, *The Long Pull*, tells the story of custom-made steel wire from design to use. The film runs 28 min and is in color. *Skylines* is the title of the second film, a 29 min color film. Shown are the modern uses of structural steel.

Down to Earth discusses the problems of heat transfer in industry. The film, made by the Avco Corp. in cooperation with the US Air Force, shows the development of Avcoite, used in the first ICBM nose cone. It is an animated color film that runs 13 min.

The Science of Making Brass is an award-winning film from the Chase Brass & Copper Co. It offers step-by-step closeups in the making of sheet, rod, wire, and tube from brass and other copper alloys. The film won a first prize in the International Competition for Technico-Industrial Documentary films at Turin, Italy, and received a Venetia Diploma at the annual Venice Film Festival. Running time for the color film is 28 min.

Heat Transfer 400° to 750°F traces the development of modern process heating. The film stresses the importance of uniform and precise temperature control in process industries operating in this temperature range. It also gives a brief review of direct fire, liquid phase, and

(Continued on page 274)



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GREFCO...inventors of internally plated brick and pioneers of the all-basic open hearth furnace.

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PATENTED "EE" BRICK

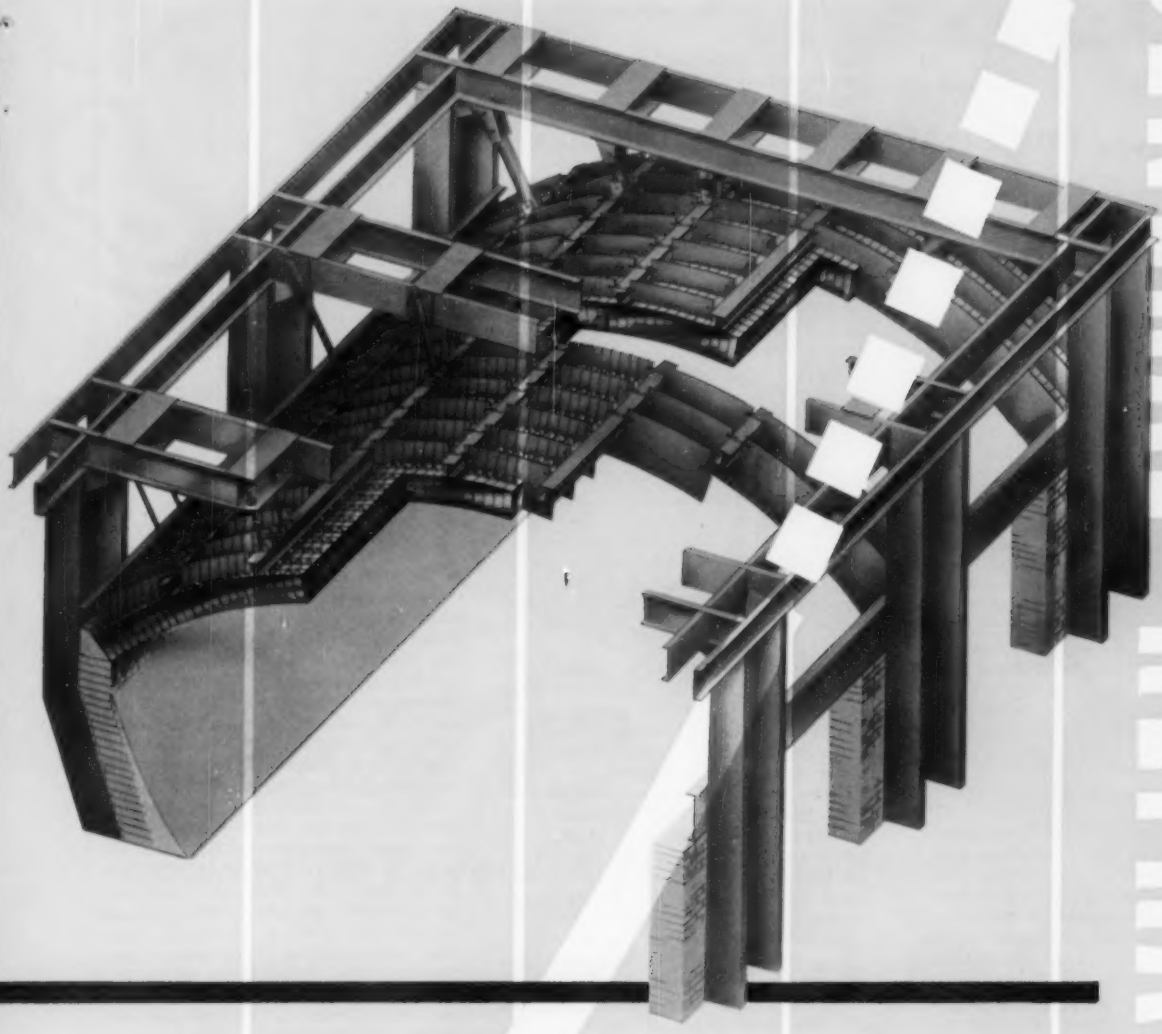
Increasing use of All-Basic Open Hearths

● More than one third of American steel is now produced under basic roofs. 250 of the 900+ open hearth furnaces in the country are now all-basic. Over 90% of the current basic roofs in America are built from brick containing internal plates, GREFCO's invention.

More and more open hearth furnaces are being converted to all-basic roof construction every week. Projected schedules predict that the majority of large open hearth shops will be all-basic before the end of 1960. Virtually all of these programs are predicated on the use of double internally plated, chemically bonded, basic brick.

GREFCO's invention of the process for chemically bonding magnesite and chrome based refractories is only one of its major contributions to the development of the successful American all-basic open hearth furnace. GREFCO's invention of "Tab" brick for suspending basic brick cut the costs of suspended basic structures greatly. GREFCO's more recent invention of internally plated brick provided markedly improved service life to basic roof refractories. In many cases, the addition of internal plates to basic roof brick has been demonstrated to yield an increase in roof life from 25% to 50%, or more.

Because of the far reaching need for such brick, GREFCO has licensed many other



refractories producers, both here and abroad, to produce internally plated brick. This has insured the brick's availability to the steel industry.

Throughout the development which has culminated in today's all-basic open hearth, GREFCO's research, sales-service and sales personnel have observed, studied, and suggested improvements. Many features of current construction design and many time-saving techniques of construction were suggested originally by GREFCO men. GREFCO now has a staff of qualified and experienced men whose major duty has been to help in the development and installation of all-basic open hearths. These men have assisted with basic construction in almost every plant where basic roofs are used. Their background in engineering and masonry experience with basic roof structures is unequalled in the American refractories industry. GREFCO offers the services of all its facilities for research, engineering, and construction advice, as well as for superior basic refractories to help you with your basic furnace problems.

For "know-how" and prompt service on all basic refractory problems, call your GREFCO representative.

GENERAL REFRACTORIES CO.
Philadelphia 2, Pa.

GENERAL REFRACTORIES

1959 1960 196

OPPORTUNITIES
IN
IBM
RESEARCH

ENGINEERING METALLURGY

The IBM Research Center in Westchester County, New York, has an excellent opportunity for either a metallurgist or an engineer with a good background in the mechanical behavior of materials.

The assignment, involving both basic and applied problems, will be concerned with material characteristics such as creep and fatigue. Representative examples of projects will include studying the effect of fretting and stress localization on fatigue life, or investigating the creep of materials under conditions of multiaxial stress.

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Advanced degree in Metallurgy or Engineering. In addition, you should be familiar with the applications of metals in industry and be capable of formulating a research program related to the needs of an engineering organization.

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Yorktown Heights, New York

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INTERNATIONAL BUSINESS MACHINES CORPORATION

EDUCATION

(Continued from page 271)

vapor phase heating methods before concentrating on the Dowtherm vapor-phase heating in the above mentioned temperatures. Produced by The Dow Chemical Co., the film runs 22 min, and is in color.

Ion Exchange is another Dow product, this time telling the story of chemical processing through animation. Beginning with a summary of ion exchange's fundamental principles, the film goes on to review the types of ion exchange resins available . . . operating variables . . . and mechanical procedures. The film is designed for both the chemical and process engineer, as well as the undergraduate student. The color film runs 16 min.

The Drop Forging Association has presented the complete story of modern closed die forging methods in *Forging in Closed Dies*. Slow motion sequences and cutaway models help explain the design and making of dies, the varieties of metals used and how they are selected, and many other topics. The film is in color and runs 28 min.

Progress in Modern Basic Refractories describes and explains chemical and physical properties of modern basic refractories . . . the reasons for their increased use . . . how they are produced . . . and where and how they are used to line the many types of furnaces that produce steel, copper, glass, and cement. It also deals with the nature of materials at melting temperatures, and their effects on refractory structures. The film comes from the chemicals division of Kaiser Aluminum & Chemical Corp. Running time for the color film is 17 min.

Research & Development at the M. W. Kellogg Co. shows the Company's research in thermite reactions, fluidization, and miniaturized plants. Also accentuated is Kellogg's concept of cooperative research and development. The film is in color and runs 17 min.

A 35 min color film produced by Rensselaer Polytechnic Institute (under a grant from Perkin-Elmer Corp.) details the story of *Infrared Spectroscopy*. Both theory and practice are depicted, including electromagnetic wave theory, and uses animation to explain the energy of molecules, moments of inertia, types of rotators, and fundamental fibrations.

The Ninth Element tells the story of titanium from black ilmenite powder to white pigment. Though not ninth in the periodic table, the element is ninth in world usage. As one who has seen it, this reporter can recommend the 35 min color film. The film is by courtesy of Titanium Pigment Corp., subsidiary of National Lead Co.

The history of galvanized steel unfolds in *The Story of Softite*, a 16 min color film produced by the Wheeling Steel Corp. The film offers a step-by-step tour of a modern plant, showing the metal from basic ore to finished product.

These films are available on free loan from the Modern Talking Picture Service headquarters—3 E. 54th St. New York 22, N. Y.—or its branch offices: 714 Spring St., Atlanta 8, Ga. . . . 216 E. Superior St., Chicago 11, Ill. . . . 1308 Slocum St., Dallas 7, Tex. . . . 2400 W. Seventh St., Los Angeles 57, Calif. . . . 21 W. 60th St., New York 23, N. Y. . . . and 444 Mission St., San Francisco 5, Calif.

► Pennsylvania State University has approximately 3000 films, filmstrips, recordings, and slides available to recognized schools, institutions, and other organizations.

For more information, contact the school's Audio-Visual Aids Library, University Park, Pa.

Liquid Metal Research

► Erosion and cavitation caused by the heat removal media used in nuclear power plants is under investigation by Frederick G. Hammitt, of the Mechanical and Nuclear Engineering departments, University of Michigan. Liquid metals such as mercury, sodium, sodium-potassium, and lead-bismuth are used in nuclear power plants as heat removing media or power plant working fluids. Cavities, or *bubbles*, get into a pump's high-pressure region (near the blade discharge section) and collapse in a violent reaction that can break down the strongest materials, Dr. Hammitt explains. "When liquid metals are used, a chemical reaction accompanying cavitation may increase the breakdown of materials," he continues. "The mechanics by which this is caused are not thoroughly understood. And one of the unknown factors is the quantity of erosion to be expected from cavitation in high-temperature liquid metals."

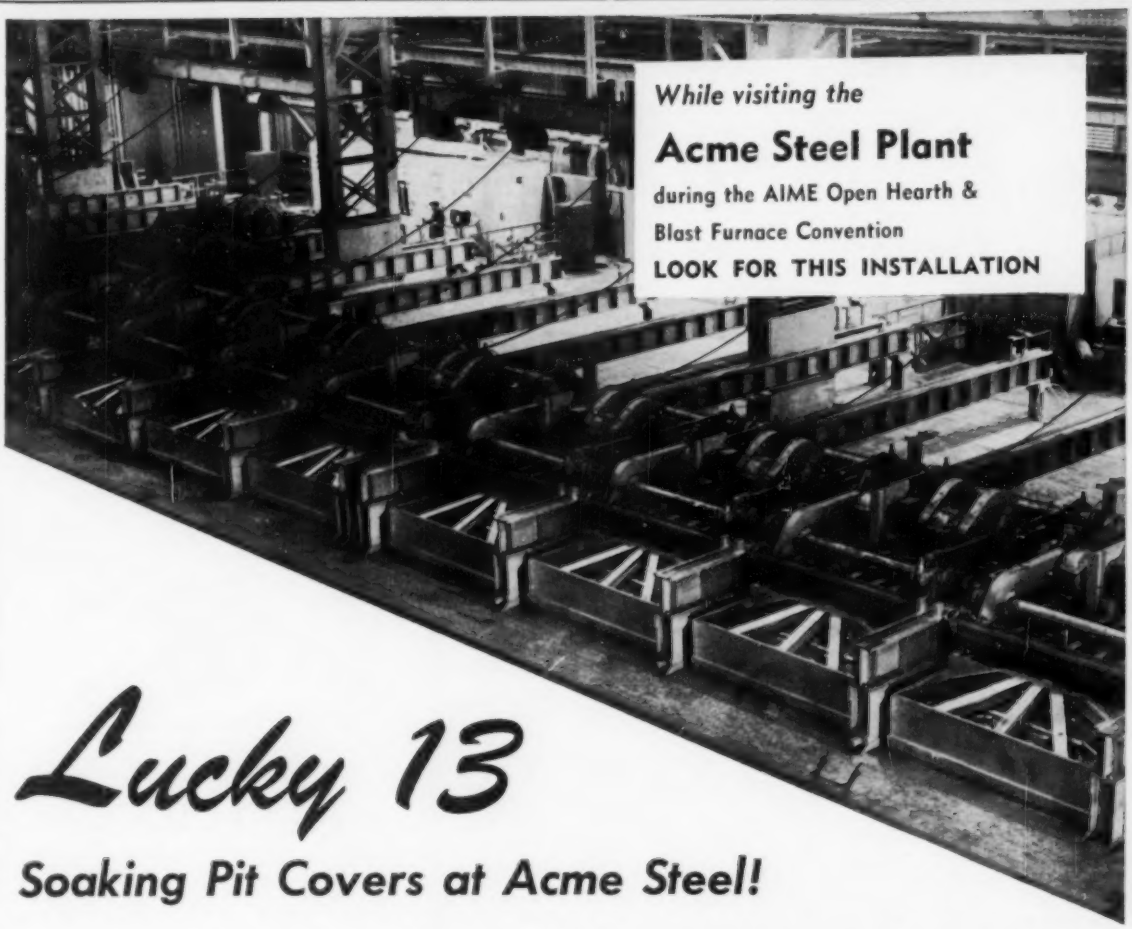
Sponsor of the project is the National Aeronautics and Space Administration, which is interested because of possible application of liquid metals to power generation in future space vehicles.

Case Gets New Building

► Case Institute of Technology has begun excavation on a new $2,300-000 metallurgy building. When completed, it will be six stories high and comprise 71,450 sq ft of floor space. Scheduled for completion in September 1961, the building will provide room for approximately twice the present metallurgical faculty and student body.

Metal processing equipment and liquid metal facilities (including a 250-kw induction heating unit capable of melting a ton of steel) will

(Continued on page 277)



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editorial

Which System . . . English . . . or . . . Metric?

Are there advantages in a change over? Can we afford the costs?

Questions like these were taken up at the Tenth National Conference on Standards, sponsored by the American Standards Assn. in October 1959.

Upon hearing of the debate, an initial impulse might be to jump to the cause of the metric system as the most widely-recognized international standard. But upon reading the papers presented at the Conference and upon further reflection, the answer is not a simple "yes" or "no". There are good arguments on both sides, and some of them presented at the Conference are as follows:

R. W. Ernsberger of Eli Lilly & Co.—one of the few manufacturers in the US that has converted its internal manufacturing operations to the metric system—had this to say: "We made this conversion for three good, hard, profit-making reasons." The first was that, "we felt that we could save money if we were to convert to the metric system from the system of pounds, gallons, grains, grams, that we had always used." The second reason was "because of the opportunities to reduce errors through the establishment of a consistent and a straightforward method of computation." And the third reason had to do with the nature of the business, "Lilly is engaged in a world-wide operation."

But Mr. Ernsgerger added that, "There are many arguments, pro and con, as to the merits of one system of measurements over another, depending upon where you sit and what the world looks like to you." Furthermore, "Our engineering department has not changed to the metric system in drawing up our prints and installing our equipment."

Randolph Hawthorne of the magazine, *Space/Aeronautics* had stronger views. "You have only to look at the trend to the metric system throughout the world to see that the inch-pound users are a distinct and shrinking minority. India and Japan are the latest nations to go metric." He pointed to our handicaps in exporting to the metric world, the time spent on English-metric conversions, and the "far more onerous" conversions within the English system. The costs of a change-over are unknown, but "That it can be done by a highly industrialized nation is shown by Japan, which shifted to the metric system the first of this [1959] year."

Taking an opposing view was Ralph M. Drews of Republic Steel Corp. Pointing to the "billions of dollars in drawings in our engineering files", he emphasized that "All of this has been engineered to the American measurement system. To change now to the metric system would require re-dimensioning of our entire file of drawings with cumbersome metric decimals, requiring a large number of figures in order to make new parts fit accurately." In addition, he found the benefits to be brought to the American producer and consumer "quite confusing". "Products made to metric system dimensions of simple numbers are in no way interchangeable with products made to the inch system. For example, a 2-cm bolt cannot be used in place of a ¼-in. bolt, and a standard metric-dimensioned pipe will not interchange with a standard American pipe. If the conversion is to be made by adopting the existing metric-country standards . . . and by continuing to manufacture to the inch system for existing requirements, we might never get out of the mess . . . It would mean dual stocking of parts from now on. It could even mean producing equipment operating with sections made to both measurements." As regards the export question he pointed out that "domestic versus export demand must be considered."

(Continued on opposite page)

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Editorial Cont. . . .

Mr. Victor Raviolo of Ford Motor Co. was "shocked at the superficial thinking that has led to a serious consideration of this kind of conversion of the American economy. It is ridiculous when you consider the percentage of our national wealth that exists in the form of physical things . . .

"There is no way . . . that we can make a definitive survey of the cost of changing to a new system of weights and measures. At a minimum, it would cost many billions of dollars." As for Ford Motor Co., a rough estimate shows that it would dissipate something between one sixth and one fifth of the total value of the company in conversion and . . . would have accomplished nothing at the end of it. We would have no advantage at all for it." He noted that "English measures are handy because they are related to natural sizes; for example, the pint, the quart, and the gallon. The liter is nearly a quart; the next smaller unit is a deciliter; the next large is a decaliter, which is nearly a barrel.

"Fine machine work requires the use of precise specifications in measurements, and many industries have established the decimalized inch as a means of avoiding the conversion of fractions to decimals in each calculation . . . There is no difficulty in using the decimalized inch within the English system. In this regard, there is no advantage over the metric system, but neither is there any disadvantage."

As to foreign trade, W. J. Darmody of The Sheffield Corp. had this to say, "Today there is in some quarters a feeling that foreign trade might be stimulated by US conversion to metric units. It should be borne in mind that this could be a two-way street, and foreign sources might find it advantageous in their low-cost penetration of some of our present markets such as spare parts for American products." Furthermore, "We should not visualize US manufacture in metric units as something difficult or beyond our capabilities . . . A large American facility has designed and manufactured turbines in metric units for about 50 years. Many of our largest American manufacturers have extensive experience in manufacture to metric units in their foreign operations."

A note of accord appeared to have been reached in the discussion when it was pointed out that, "The increased use of the decimal inch by American industry is an effective compromise on the metric dimensioning question . . . it provides the recognized advantages of the metric system without abandoning the inch unit."

What do JOURNAL OF METALS readers think about the question of "Which System . . . English . . . or Metric?"

FWS

letters
to the editor

Bravo!

Your editorial *Your Magazine* in the January 1960 issue of the JOURNAL OF METALS was read with considerable interest. You and your staff are to be commended for the excellent work you have done on improving the JOURNAL. It is now more readable and of more interest to the members. I personally have read more articles in the JOURNAL since you have changed its format. (For example, I even read the editorials.) Again, many thanks for the splendid job you have done in improving the quality of our magazine.

G. H. Schippereit
Technical Advisor
Battelle Memorial Institute

Suggestion

I am a member of the AIME and I read the JOURNAL OF METALS (as you hope).

I would like to comment a little on papers published in the JOURNAL and submit a suggestion.

I have noticed that less space in the JOURNAL has been devoted to the operating practice of steelmaking.

For example, I read in the January issue that at the Buffalo meeting, NOHC, held on Nov. 10, 1959, a number of papers were presented on the competition between LD and OH, and on use of oxygen in the OH.

In the same January issue I read of a paper on oxygen in the OH, presented at the Annual Meeting by the Linde people, and of a number of papers on LD presented by Kaiser and J & L people at the same meeting.

Would it be possible to have at least the most significant papers of this kind published in the JOURNAL?

I believe this would make the JOURNAL even more interesting for the operating people than it is now.

Giorgio Massobrio
Open Hearth Supt.
Cornigliano, S.p.A.
Genova, Italy

[The JOURNAL OF METALS must cater to all its readers, and their interests spread from nonferrous extractive metallurgy through iron and steel, and into physical metallurgy, metalworking, and research. We try, as best we can, to provide informative articles in each of these areas.

Specifically, in answer to your letter, many of the local meetings of NOHC are off-the-record, and, as such, we cannot publish the papers which are presented. In the special case of the Buffalo meeting, we did feel that some of the papers were particularly important, and we tried to obtain permission for publication from the firm's concerned. Unfortunately, this did not prove possible.

The Linde paper on the use of oxygen in the open hearth appears in this issue (p. 327). As for the AIME Annual Meeting papers on LD and other oxygen steelmaking processes, you will find most of these papers, plus others, in the July issue, which will give special emphasis to oxygen steelmaking processes.—Ed.]

EDUCATION

(Continued from page 274)

be housed on the first floor. Service shops and the mechanical testing area will be on the second floor. Classrooms and laboratories will make up the third floor, while special laboratories and a 100-seat lecture room will take up the fourth floor. The fifth floor will house the ceramics laboratory, ultra-high vacuum laboratory, X-ray laboratory, and facilities for the study of creep, stress, and fracture. The sixth floor will be devoted to non-metallurgical facilities.

Se, Te Literature

► A program of abstracting the world literature on selenium and tellurium is now underway at Battelle Memorial Institute. Much of the literature being abstracted has been translated from Russian, Japanese, and French publications and deals with the preparation and properties of selenium and tellurium and their compounds. This continuing program is expected to result in some 50 new abstracts each month. Requests for the present collection of abstracts, and others as they are issued, should be sent to the: Selenium and Tellurium Development Committee, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

Foundry Needs Cited

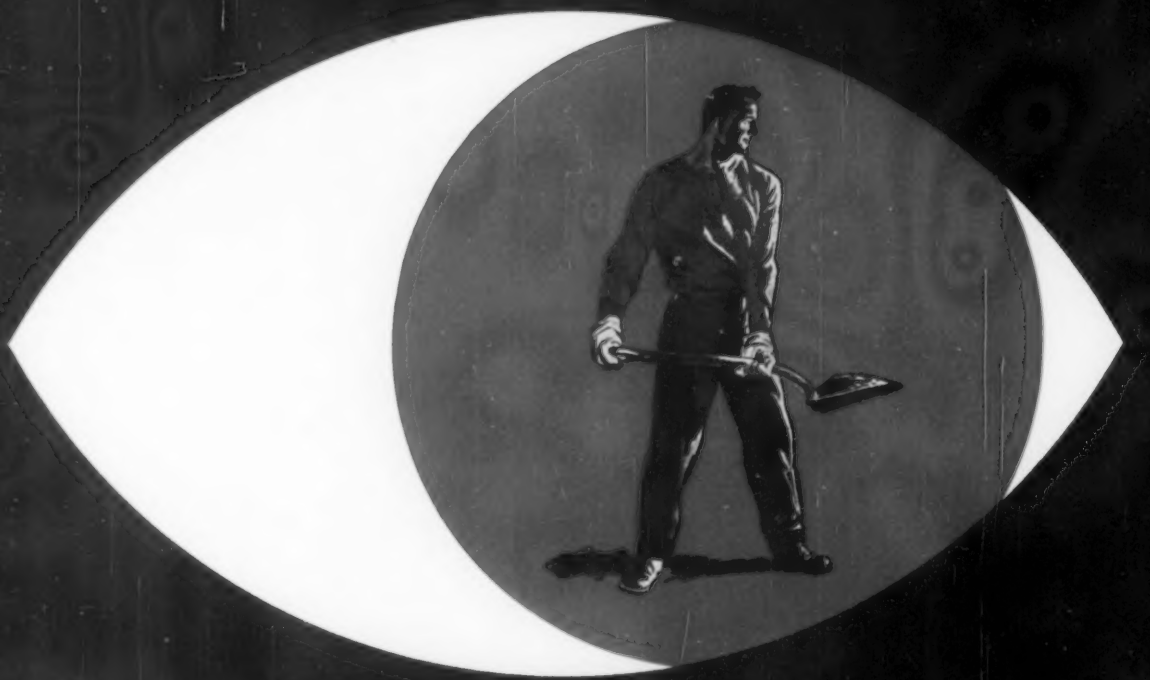
► A $509 million expenditure for modernization and expansion facilities is needed in the Nation's ferrous and nonferrous foundries, according to a study made by the American Foundrymen's Society.

"Significant in foundry plans for capital investment in the next two years is the indicated broad interest in better laboratory and testing methods," says William M. Maloney, general manager of the Society. "It [the survey] indicates that more than a half billion dollars will probably be invested in new capital equipment in the next two years," he continues, . . . "62 pct for modernization, and 38 pct for plant expansion. In addition, foundries will be spending nearly $7 billion for essential materials and supplies."

The Society officer noted that production of castings in 1960-1961 is expected to top 37 million tons. The survey also showed that industry itself expects an increased output of 15 pct this year, and 20 pct in 1961.

The American Foundrymen's Society 1960 Castings Congress and Exposition will be held at Philadelphia's Convention Hall May 9-13.

capacability



Basic reflects *Capacability* . . . the capacity to manufacture and deliver quality refractories—the *ability* of talented and creative people to do a better job through vision, resourcefulness and skill. With capacability Basic continues to develop and furnish steelmakers a complete line of better hearth lining and maintenance materials—dead-burned dolomites, ramming mixes, gunning mixes, patching materials and tar-bonded linings for the new oxygen furnaces.

basic incorporated HANNA BUILDING CLEVELAND 15, OHIO

basic's vision to meet the challenge of an expanding steel industry

We believe the word *Capasability* best typifies our philosophy . . . the capacity, ability and desire to adequately supply steelmakers with better refractories. • At Basic, product pioneering is a tradition. Most of the company's thirty ramming mixes, gunning mixes and dead-burned dolomites have become the industry's standard of performance for lining and repair of open hearth and electric furnaces. Anticipating acceptance in this country of the "L.D." oxygen converter, we were perfecting refractory linings for these new furnaces years before their introduction. • Keeping pace with increased steel output, Basic continues to expand its Ohio and Nevada manufacturing facilities. Strategic location of these plants permits rail and truck shipments virtually . . . at the flick of a finger. As a result, steelmakers look to us as a quick and absolutely dependable source of supply. • Our sales and service staff is comprised of men with broad steel-making experience and technical background. This on-the-floor assistance is an important "plus" when refractory problems arise. With experience, vision and capacity, Basic will continue to meet the challenge of the dynamically expanding steel industry. For more information about our refractory materials, write for the new 24-page booklet, "Products of Basic"

Millions of tons of Basic's dead-burned dolomites, *Magnefer* and *Syndolag*, have been employed by the steel industry to fettle open hearth and electric furnaces.

Pioneering guns and gunning mixes such as *Gundol*, *Gunmix* and *Gunchrome M*—basic supplies steelmakers with a complete line of these important maintenance refractories.

Basic's development of the ramming mixes, *Ramset* and *Ramclase* has contributed immeasurably to decreased furnace downtime and also to quick hearth installation.

Continuing its leadership, Basic furnishes tar-bonded refractories, *Tarblok* and *Tarmix* for the linings and maintenance of oxygen steel-producing furnaces.

personals

George Kromen is now plant manager of the American Zinc Co. of Illinois. He joined American Zinc in 1947, and comes to the position from duties as general supt.

In yet another Company promotion, **William T. Maidens** has been named technical consultant at American Zinc's Columbus, Ohio plant. He has been with the plant since 1920, and served as general supt. there until his appointment.

Elvin W. Smith has been appointed process engineer at the Parkersburg, W. Va., plant of the Carborundum Co. He was previously with the Company's Akron, N. Y., plant.

Clyde Williams is now technical director pro tem of Copper Products Development Association, Inc., a newly-formed group of copper producers. The organization was formed to conduct research and studies "for the expansion of uses of copper and copper products, and the development of new and improved copper products."

Member companies of the Association are: American Metal Climax, Inc.; The Anaconda Co.; The International Nickel Co. of Canada, Ltd.; Kennecott Copper Corp.; and Phelps Dodge Corp.

Dr. Williams was the 1947 President of AIME. He is also a former president of the Battelle Memorial Institute.

Vernon G. Kneeskern, plant manager of Reynolds Metals Co.'s St. Lawrence Reduction Plant (Massena, N. Y.) is the subject of a full-page feature story in the December issue of *Reynolds Review*, company employee's magazine.

A. E. Lee, Jr., has been appointed technical director of the Amco div., American Metal Climax, Inc. He succeeds **Douglas Tennant,** who will retire from active service June 30th. Mr. Lee was formerly in charge of the division's zinc smelting and refining operations. AIME members know him better as the 1959 Chairman of the Extractive Metallurgy Division.

Choh-Yi Ang has been appointed director of the Materials Laboratories of P. R. Mallory & Co., Inc. In that capacity Dr. Ang will direct research and development of new structural and electronic materials and processes . . . heat-resistant and semiconducting intermetallics . . . and neutron and gamma radiation. He has been with the company since 1954.

Robert L. Cleveland is now president of Tonawanda Iron, div. of American Radiator & Standard Sanitary Corp. He was previously general manager of the division.

Carl G. Hogberg is now president of Michigan Limestone div., U. S. Steel Corp. He joined U. S. Steel as a blast furnace apprentice in 1935. He moved on to Pittsburgh in 1941, and became asst. to the vice president, Michigan Limestone div., in 1955. Mr. Hogberg received the Iron and Steel Division's J. E. Johnson, Jr. Award in 1945.

A. C. Keller has assumed the position of works manager at the Aliquippa works of Jones & Laughlin Steel Corp. Formerly asst. works manager, Mr. Keller has been with the Aliquippa facility since 1925.

A. P. Miller has advanced to the presidency of Acme-Newport Steel Co. He was formerly vice president and general manager for the Company. Mr. Miller was instrumental in the organization of the Chicago section, National Open Hearth Steel Committee, serving as its chairman from 1934 to 1945. He then assumed the chairmanship of the national committee, serving 1945-1946.

Norman L. Peterson of the Massachusetts Institute of Technology, is co-developer of a metallurgical tool now finding application in the art world. Called a *microprobe*, the device is a needle a little more than one micron in diameter. The needle has been used to penetrate layers of pigment from a painting, identifying them in cross section in order to determine the age or authenticity of art objects.

Mr. Peterson described the development during a session at the annual meeting of the American Academy for the Advancement of Science. R. E. Ogilvie of MIT collaborated with Mr. Peterson on the project.

The microprobe is said to be superior to other methods of testing, based on its use at the Boston Museum of Fine Arts. "You can get down into a much finer layer," Mr. William J. Young, head of the museum's technical laboratory, has said.

Jean Vuillequez has been elected president of Lead Industries Association to fill the unexpired term of J. D. Bradley, Bunker Hill Co., who died recently. Mr. Vuillequez is a vice president of American Metal Climax, Inc.

Madan M. Nanda has recently joined the Electric Boat div. of General Dynamics Corp. as a metallurgist at the division's research annex in Groton, Conn. There he will be responsible for ultrasonic inspection of nuclear submarine weldments.

Mr. Nanda was formerly located at Brookhaven National Laboratory in Long Island.

R. Norman Holme is now technical

(Continued on page 286)

J&L STEEL

RESEARCH METALLURGISTS

Continuing growth of the J&L research and development program has created a number of openings for professional personnel, holding Ph.D., M.S., or B.S. degrees in metallurgy or a related scientific field. Projects underway or in prospect cover a diversity of subjects in physical and process metallurgy, all of course, related to the production of carbon and stainless steels, and all company supported. Because of this diversity, it is almost always possible to accommodate individual interests. The J&L Research Division is housed in the modern, air-conditioned, fully-equipped Graham Laboratory in suburban Pittsburgh. Attractive residential areas are close by. And progressive Pittsburgh offers many advantages, including full graduate programs at the University of Pittsburgh and Carnegie Institute of Technology for the man who wants to continue his professional education.

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METALGRAMS

UNION CARBIDE METALS

. . . news about "Electromet" ferroalloys and metals

APRIL, 1960

OPEN-HEARTH SAVINGS -- Economics are changing the form in which chromium is added to 4100 and 8100 series constructional steels. Melters are switching to furnace additions of new blocking chrome. Reason: Savings of $1.00 to $3.50 per ton in chromium and silicon costs. The alloy replaces exothermic ferrochrome ladle additions and provides all the silicon needed for blocking. Your Union Carbide Metals representative will be glad to give you additional information.

* * *

FASTEST-DISSOLVING FERROCHROME -- Stainless steel melters continue to be impressed with the rapid solubility of the new "Simplex" low-carbon ferrochrome. In a typical test, 5,300 lbs. of the alloy (7.7 per cent chromium added) dissolved in a 35-ton heat after refurnacing in less than 25 minutes. In addition, 4,0 lbs. of "Simplex" ferrochrome added to the ladle during refurnacing dissolved before the ladle was half full. Get further information in a new six-page folder, F-20,116.

* * *

COLORS AID IDENTIFICATION -- Bags of 50 per cent ferrosilicon, stainless and medium-carbon ferromanganese, and calcium-silicon are now color-coded for easy identification. Melters report 10 to 15 per cent higher recoveries with bagged alloys in the ladle, cutting alloy costs. In addition, bags give closer control over specifications, cut handling losses, and aid inventory control. Union Carbide Metals produces 11 alloys in bags. For color and chart showing bag specifications and colors, write for F-20,121.

* * *

QUALITY IN QUANTITY -- Each of the more than 100 "Electromet" ferroalloys and metals is carefully inspected during every step of production. The aim: To make sure that each alloy meets close chemical specifications consistently. Samples are taken during raw material preparation, furnacing, cleaning and crushing, packing, storage, and shipping. During an average month at Union Carbide Metals' Marietta, Ohio, plant, more than 30,000 tests are made on over 10,000 samples. For further details, ask for the Summer 1959 issue of UNION CARBIDE METALS REVIEW.

* * *

SAVINGS GROW WITH FERROMANGANESE-SILICON -- Several stainless melters have reported that using ferromanganese-silicon for slag reduction has increased the recovery of chromium from the slag. A drop of as much as 4 per cent in the chromium oxide content of the slag has been reported. To a melter charging 12 per cent chromium, a one per cent chromium recovery means a saving of 2.4 lbs. of chromium per ton as low-carbon ferrochrome, worth about 75 cents per ton. These savings are in addition to those previously reported -- $4 to $9 per ton for 200 series stainless and $0.75 to $1.75 per ton for 300 grades. Further facts are in a four-page folder, F-20,093.

* * *

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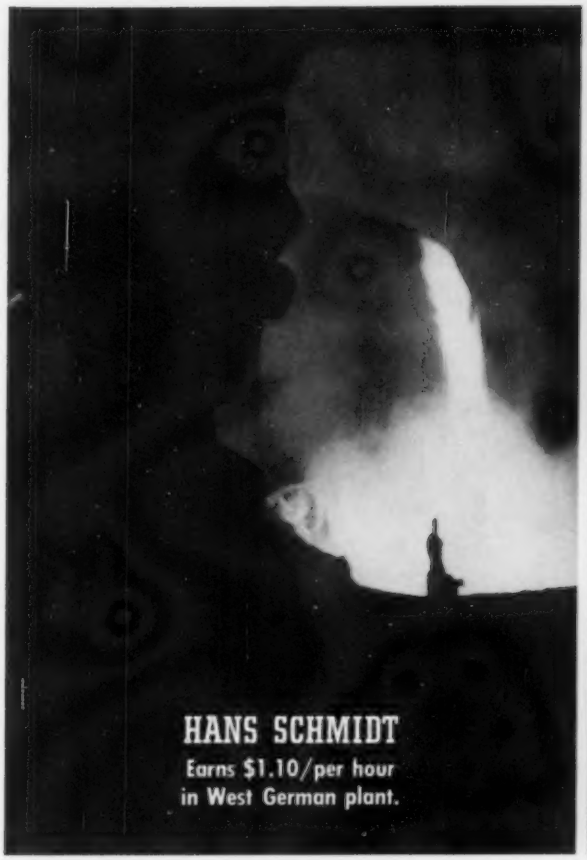

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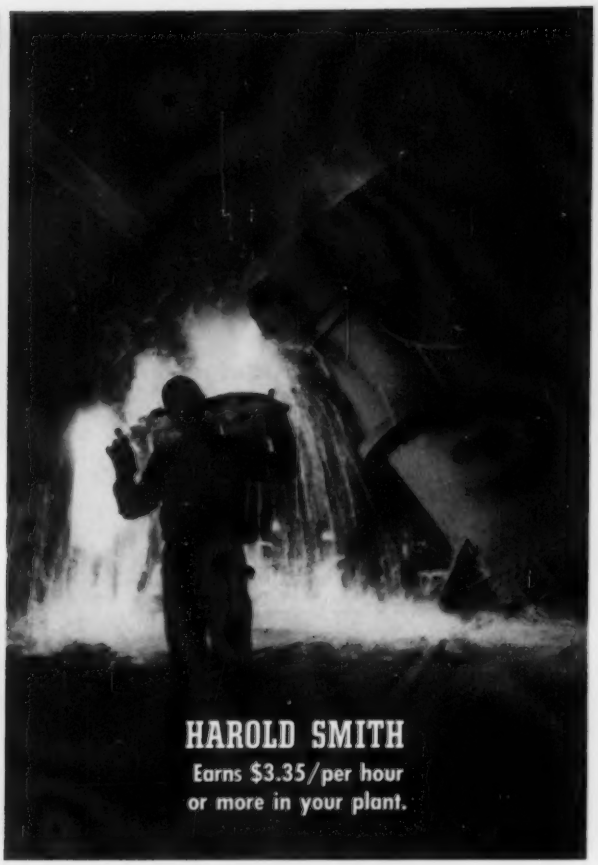

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PERSONALS

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service metallurgist and mining chemicals representative in the Latin American area for Dow Chemical International Ltd., S.A. His headquarters is Lima, Peru. Formerly, Mr. Holme was assistant chief metallurgist for Mauricio Hochschild & Cia. Ltd. in Lima.

Harry H. Kessler, president of Foundry Design Co., has been elected vice president of the Bowling Corp. of America. The holder of numerous patents in the metallurgical field, Mr. Kessler is also a leading boxing referee.

John L. Holmquist has been appointed director of research for tubular products at The National Supply Co. Formerly director of research at the Co.'s Ambridge, Pa., plant, he now makes his headquarters in the Pittsburgh general offices.

Fred B. O'Mara is now director of manufacturing for National Carbon Co., div of Union Carbide Corp. Mr. O'Mara will be located at the Co.'s production headquarters in Cleveland.

W. W. Heilman has taken over as manager of the Niagara plant of Union Carbide Metals Co., div of Union Carbide Corp. He started with Union Carbide Metals at Alloy, W. Va., in June 1941, transferring to Niagara Falls in April 1954 as asst. technical director of alloys, the Technical Control group.

Richard C. Diehl has joined Koppers Co. as a vice president in the engineering and construction division. Prior to joining Koppers, he was vice president of operations, Universal Cyclops Steel Corp. Before that, he was president of Chase Brass & Copper Co. Mr. Diehl will make his office in Bogatá, Columbia, working closely with Acerias Paz del Rio, S.A., an integrated steel company with which Koppers has just signed a management agreement.

A. W. Thornton is now general superintendent, Lorain, Ohio, works of National Tube Div., U. S. Steel Corp. Previously, he was asst. to the vice president of operations, National Tube Div. in Pittsburgh.

John G. Holmes now manages the newly-formed Central sales region of Union Carbide Metals Co., div of Union Carbide Corp. He will make his headquarters in Cleveland.

Woodrow W. Lair takes the post of refinery superintendent of the Carlsbad, N. M., facility of the U. S. Borax & Chemical Corp. He was asst. refinery superintendent previously.

James L. Oberg has been appointed a vice president of Metal & Thermit Corp. He will continue to hold his present assignment as general manager of the Corp.'s Metals and Minerals div.

C. Burton Clark is now research supervisor for fused refractories, metal industries, located at the Harbison-Carborundum Corp. in Falconer, N. Y. Mr. Clark joined Harbison-Walker's research staff in 1937, his last previous position begin senior minerologist on the staff. Harbison-Carborundum was recently formed through agreement between Harbison-Walker Refractories Co. and Carborundum Co.

Herbert J. Shaner has been promoted to division manager of The Ramtite Co., refractory manufacturing div. of The S. Obermayer Co. He was formerly district manager of Chicago, and will continue to keep office in Chicago.

Robert M. Kibby has been appointed manager of reduction research for Reynolds Metals Co. He will continue to be based at the Co.'s Listerhill plant near Sheffield, Ala., where he headed the reduction laboratories.

Harold T. Clark has assumed the newly-created position of administrative director of the research and development dept., Jones & Laughlin Steel Corp. In this position, Dr. Clark will be responsible for supervising general administrative affairs of the department, patent matters, long-

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range planning of departmental objectives and facilities, and other technical assignments. He joined J & L in 1936, rising to the rank of director of research, his last previous assignment.

Helmuth W. Schultze is now director of commercial sales and development for The Alloyd Corp. In this newly-created position, Dr. Schultze will be responsible for the sale and commercial development of new materials and chemicals produced by Alloyd. He comes to the job from the the Climax Molybdenum Co., div of American Metal Climax, where he was manager of new chemical and catalyst development.

Harry G. Schwab takes over as director of manufacturing for The Bunting Brass & Bronze Co. He will be responsible for both the Toledo, Ohio, and Kalamazoo, Mich., operations of the Company.

A. C. Jephson recently came in for some publicity in the *ASARCO News*, employees' magazine of the American Smelting and Refining Co. Mr. Jephson is manager of the Co.'s Corpus Christi, Tex., plant.

William B. Wallis has become a full-time consulting engineer for the Strategic Materials Corp. He will assist in the promotion of Strategic-Udy processes.

C. Baldwin Sawyer is now chairman of the executive committee on the board of directors, The Brush Beryllium Co. Dr. Sawyer, who has been board chairman, counts among his many activities contribution to the development of the atomic bomb.

J. G. Dick has been appointed manufacturing manager of all divisions of the Canadian Bronze Co. Ltd. Mr. Dick was formerly district manager of Montreal Bronze Co. Ltd., div of Canadian Bronze Co. Ltd.

Roger M. Wolcott is now assistant director of production planning programs in the Production Planning Program div., Jones & Laughlin Steel Corp. Mr. Wolcott comes to this newly-created position from the job of assistant to the vice president—Engineering and Plant.

Joseph V. Emmons has retired from his duties as director of laboratories for The Cleveland Twist Drill Co. However, he still remains on the Co.'s Board of Directors. Mr. Emmons has since opened an office as consultant in physical metallurgy and metallurgical research.

R. L. Pope has taken the job of manager of the Marketing Research div of Union Carbide Metals Co., div. of Union Carbide Corp. With the Co. since 1952, Mr. Pope's last previous position was that of manager of the Cleveland sales district.

Paul D. Terrien has been given a new assignment by the Electrode div of Great Lakes Carbon Corp. Mr. Terrien has been named sales representative for the division's Midwest area. He was formerly sales representative in the Pittsburgh office.

Harold Edwards White, an AIME member since 1916, was recently honored in the commemoration of a new Lava Crucible-Refractories Co. laboratory in Zelienople, Pa. Called the Harold Edwards White Research Laboratory, it is dedicated to the 30 years of service which its namesake has devoted to the company. Mr. White is vice president of the firm. The dedication ceremonies were publicized in pictures and text in the *Butler Eagle* of Butler, Pa.

Robert T. Luedeman is now chief engineer for materials in the Weston Instruments div. of Daystrom Inc. Before his new appointment, Mr. Luedeman was assistant chief engineer and section chief in the Metallurgy div. of Research Development.

John G. Ziemann has been named chief metallurgist of the Metals div., Kelsey-Hayes Co. Mr. Ziemann came to Kelsey-Hayes in 1957 as a research metallurgist. He became asst. chief metallurgist last June.

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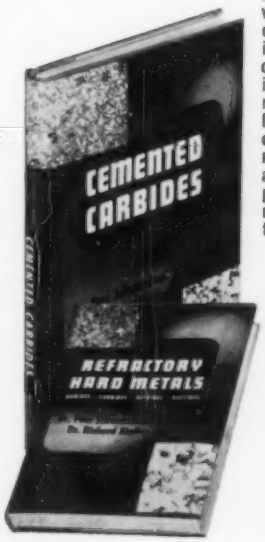

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ABOUT THE AUTHORS:—Dr. Paul Schwarzkopf is the inventor of the multi-carbide hard metals used today in 75% of carbide tool materials. A pioneer in the development and production of molybdenum parts, contact materials and heating elements vital to the electrical and electronic industries, **he holds several hundred basic patents in the field of powder metallurgy.** Dr. Richard Kieffer is a ranking authority in the field of hard metals. A contributor to scientific periodicals, he has written a number of important technical books.

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BOOKS

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Electrochemistry . . . and Organic Chemistry. •

Extractive Metallurgy, by Joseph Newton, *John Wiley & Sons, Inc.*, 532 pp., $9.75, 1959—This book is essentially an extension of the author's **An Introduction to Metallurgy,** 2nd edit. It is meant as a text for a first course in extractive metallurgy and discusses basic principles rather than detailed practices. A unit process method rather than a metal-by-metal presentation of extractive metallurgy is followed. In addition to conventional extractive metallurgy subjects, the book touches on metal crystals, equilibrium diagrams, and Gibbs' phase rule, topics normally introduced in physical metallurgy courses. Since students sometimes take extractive metallurgy before physical, the author has seen fit to include these disciplines. Mr. Newton, an AIME member, is professor of metallurgy and head of the department of mining and metallurgy, University of Idaho. •

The Influence of Sheet Thickness on Tensile Properties of Metal Sheet, by Alfred Rudnick and Robert L. Carlson, Defense Metals Information Center, Battelle Memorial Institute, 505 King Ave., Columbus, Ohio, 17 pp., 1959—The need for more information on the problem of ductility by users of high-strength alloys inspired this paper. Ductility in a given material, say the authors, is a function of several factors, including temperature, strain rate, and state of stress. The one specific problem dealt with in this paper is the effect of sheet thickness, or specimen geometry on measured ductility in a sheet-metal tension test. The conclusion the authors come to is that there is no significant influence of thickness on strength and that uniform elongation may be a more significant index of ductility than is the commonly used total elongation.

Order the paper, DMIC Memorandum 5, through the *Office of Technical Service, Dept. of Defense, Washington 25, D. C.*

Vacancies and other Point Defects in Metals and Alloys, Institute of Metals, London, England, 238 pp., $6, 1958—A collection of papers that discuss point defects and the mechanical properties of metals and alloys at high and low temperatures . . . the effect of lattice defects on some physical properties of metals . . . point defects near the surface of a metal . . . point defects in relation to diffusion in metals and alloys . . . and the mechanical properties of ionic crystals. •

Welding and Brazing of Molybdenum, by N. E. Weare and R. E. Monroe, Metals Information Center, Battelle Memorial Institute, 47 pp., $1.25, 1959—This literature survey identifies the best methods for welding molybdenum to itself. Metallurgical considerations involved in joining the metal are discussed, as are cleaning and testing techniques. Joining processes examined include fusion, resistance, and solid-state welding, and brazing.

Order from the *Office of Technical Services, Dept. of Defense, Washington 25, D. C.*, using the code number *PB 151063.*

Symposium on Electron Metallography, by the *American Society for Testing Materials*, Philadelphia, 126 pp., $4, 1959—The 11 papers which comprise this volume cover the field of electron metallography from direct transmission electron microscopy to electron probe microanalysis, studies of the microstructure of age-hardenable and heat-resistant alloys, and new techniques in speciman preparation and replication. •

Some Factors Involved in Forging Titanium and Titanium Alloys, R. B. Rich, Watertown Arsenal, 36 pp., $1—Prepared for the US Army Ordnance Corps, this treatise examines three grades of titanium—commercially pure RC-55 and RS-55, RC-

(Continued on opposite page)

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Specific examples of the environments which have been studied at Allied Research include those resulting from nuclear explosions, general aerodynamic heating, vacuum, and corrosive media. The effects of these environments on materials performance have been investigated. Other work has involved the effects of high pressure, high and low temperature, vibration, internal and external forces, radiation, erosion, thermal shock and shock loading on matter.

The man we want will expect to help direct our thinking in one or more of these diverse areas of metallurgy. He will welcome the opportunity of working with men of broad experience in Solid State Metallurgy and Physics, Deformation Behavior of Materials, Environmental Effects on Materials, and in many other related areas.

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RESEARCH • ENGINEERING • DEVELOPMENT

BOOKS

(*Continued from page 288*)

130A and Ti-150A. After impact forging at 1300° to 2100°F, studies indicated that the flow stress of RS-55 decreased rapidly up to 1700°F; while the decrease was very small thereafter. In RC-130A and Ti-150A the flow stress was approx 20 pct less for each increment of temperature above 1700°F. The forging behavior of RC-130A and Ti-150A were found to be similar. The alloys were also discovered to be insensitive to change in strain rate, especially at higher temperatures. There was a decrease in plastic strain at high strains for RS-55 with increasing energy per unit volume. This decrease appeared to be related to an increase in bottom face friction. The most promising lubricant used in the experiment was reported to consist of a 1:1 mixture (by volume) of silicone oil plus an aluminum-magnesium silicate powder.

To order, refer to *PB 151274*, Office of Technical Services, US Dept of Commerce, Washington 25, D.C.

The Properties of the Rare Earth Metals and Compounds, Rare Earth Research Group, Battelle Memorial Institute, 214 pp., $10, 1959—The most recent data on the 15 rare earth metals, plus yttrium—closely associated with the rare earths—is outlined in this handbook. Detailed descriptions are given of their physical, crystal, chemical, mechanical, electrical, magnetic, nuclear, and thermodynamic properties. A reference list of sources for rare earth information is also provided.

Electrochemistry of Molten Alkali and Alkaline Earth Halides Containing Halides of Titanium, C. T. Brown and others, 141 pp., $3,—This study, undertaken for the Office of Naval Research, examined electrochemical properties of alkaline earth halide systems of possible use in the electrolytic production of titanium. Electrolytes studied were Li_2TiF_6, NA_2TiF_6, and K_2TiF_6. Experimental methods included electrical conductance and cryoscopic, or freezing point, measurements. Studies of thermal stability and hydrolysis of Li_2TiF_6 produced the significant indication of a direct thermal dissociation leading to the formation of LiF and TiF_4 as decomposition products. The hydrolysis study confirmed the formation of a oxyfluoride. Among other results, the specific conductance of the KCl-LiCl eutetic mixture containing NaCl, LiF, NaF, KF, Li_2TiF_6, Na_2TiF_6, and K_2TiF_6 is reported as a function of both temperature and concentration of each solute.

Refer to *PB 151155* when ordering through the Office of Technical Services, Washington 25, D. C.

Repartition du Potentiel et du Courant dans les Electrolytes (Division of Voltage and Current in Electrolytes), by Robert H. Rousselot, *Dunod*, Paris, 85 pp. (paper), approx. $2, 1959—This instructive work on electrolytes is accompanied by descriptions and methods imposed by the author. The Hull cell, in particular, is treated in detail. The electrolytical deposition of metals is also handled in detail in this French language manual. •

Property Measurements At High Temperatures, by W. D. Kingery, *John Wiley & Sons, Inc.*, 416 pp., $16.50, 1959—The factors affecting properties of materials and their measurement at temperatures above 1400°C (2550°F) is the grist for this treatise. All important high-temperature properties are discussed, including heat conduction and radiation, density and thermal expansion, strength, elasticity of solids, viscosity, electrical and magnetic properties, and surface energy. The author, an award-winning member of the American Ceramic Society, examines the most suitable method for determining each property at high temperatures and provides a basis for comparing various techniques of measurement. •

Kinetics of High-Temperature Processes, edited by W. D. Kingery, *The Technology Press of MIT and John Wiley & Sons*, 326 pp., $13.50, 1959—This volume represents the results of a Conference on the Kinetics of High-Temperature Processes, held at the Massachusetts Institute of Technology in 1958. The editor, associate prof. of ceramics at MIT, was chairman of the Conference. Concentrating on high-temperature processes in general and non-metal systems in particular, the book records efforts to establish an interdisciplinary understanding of the field and application of it to real systems. •

The Sequestration of Metals, by Robert L. Smith, *The Macmillan Co.*, 256 pp., $8.50, 1959—After defining sequestration and explaining the nature of dative valency, the author considers the chelate ring and the influence of ligand and metal on strength of bond. General consideration of competitions in chelate systems is then followed by the chemical and physical properties of the various types of sequestering agents. •

Theoretical Elasticity, by Carl E. Pearson, *Harvard University Press*, 218 pp., $6, 1959—Modern methods and results in the field of theoretical elasticity are discussed in this work. Topics covered include stress, deformation, thermoelasticity, time-dependent problems, and nonlinear elasticity. An extensive background in mathematics is not needed, and

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RESEARCH & DEVELOPMENT

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A Ph.D. in Metallurgy or Metallurgical Engineering and experience in research and basic development are required. Salary open.

Send detailed confidential resume to:

Box 7-JM

NYU Summer Courses in Metallurgy Listed

June 2nd and 3rd will be the dates of New York University's fourth annual summer conference on Vacuum Metallurgy. To be held on the College of Engineering's Bronx campus, the meeting is designed to acquaint practicing engineers with advanced engineering information on vacuum metallurgy and the latest research developments in the field.

June 13-17 will be devoted to a one-week course on Thermoelectric Materials and Devices. It will consist of lectures and panel discussions on the latest theory and materials in the field, and detailed discussions of the newest devices based on thermoelectric effects.

June 27-31 will find a course on Materials and Design going on at the University Heights campus. The use of materials in today's design . . . materials science and the fabrication of materials . . . environmental analyses of materials . . . design requirements with respect to stress, temperature, chemical and electrical applications . . . and radiation problems will be topics under discussion.

Then, on Sept. 12th and 13th NYU will hold its annual Conference on Titanium Metallurgy.

For further information on each of the four programs, contact: *Mr. M. Berk, Department of Metallurgical Engineering, New York University, University Heights, Bronx 53, N. Y.*

NEW YORK UNIVERSITY

announces the presentation of

THREE SUMMER MEETINGS

in its Metallurgy and Solid State Technology Program

CONFERENCE ON VACUUM METALLURGY

June 1-2-3, 1960

A conference on new research and advanced engineering information in vacuum metallurgy.

Fee: $20.00

COURSE ON THERMOELECTRIC MATERIALS AND DEVICES

June 13-17, 1960

An intensive lecture series designed to bring engineers up to date with the theory and state of the art of materials and devices based on the thermoelectric effects.

Fee: $110.00

CONFERENCE ON TITANIUM METALLURGY

September 12-13, 1960

The 6th Annual Titanium Conference will be concerned with progress in welding, heat treatment, alloy development and corrosion of titanium.

Fee: $15.00

Dormitory accommodations, $3.50 a night. Registration will be limited. For further information contact Mr. M. Berk, New York University, University Heights, Bronx 53, N. Y. LUdlow 4-0700, Ext. 205.

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METALLURGIST

Interesting position open in the Metallurgy Department of a large industrial materials research laboratory for a metallurgical engineer with 3-5 years experience, preferably in high temperature work, to apply metallurgical principles to the development of cermet materials. Replies held in confidence.

Reply to Box 5-JM

SENIOR METALLURGIST

Excellent opportunity for a metallurgist with Ph.D. or equivalent to apply metallurgical principles to the hot forming of inorganic materials and cermets. Research program will involve fundamental studies of deformation mechanisms of ceramics and their applications. Replies held in confidence.

Reply to Box 6-JM

SENIOR METALLURGISTS: To plan, direct, carry out materials research and development in the nuclear field. Opportunities exist for both applied and basic work in a new laboratory. Currently in progress are programs in thermal stress fatigue, alloy development, high temperature properties, fuel element development, ceramic coating techniques and properties. An advanced degree and/or experience in the nuclear field would be desirable. Send resume to Dean W. Townsend, Advanced Technology Laboratories, Division of American-Standard, 369 Whisman Road, Mountain View, California.

BOOKS

(*Continued from page 289*)

background material is provided where necessary. •

Summaries of Physical Research in Metallurgy, Solid State Physics and Ceramics, edited by Ralph R. Nash for the Atomic Energy Commission's Division of Research, 204 pp., $2.75, 1959—This paper-bound document serves as a directory to research in the above mentioned fields and is meant to assist researchers in exchanging ideas by acquainting them with related programs at other laboratories. It summarizes the objectives and current status of individual research projects supported by the Metallurgy and Materials Branch of the AEC's Division of Research in physical metallurgy, solid state physics, and physical ceramics. The document includes research conducted at AEC laboratories, as well as that done by university and other laboratories. Two indexes appear at the end of the directory, one arranged by subject, the other alphabetically by contractor. Order *TID-4005 (Pt. I, 5th Ed.)* from the *Office of Technical Services, Dept. of Commerce, Washington 25, D. C.*

Progress in Cryogenics, Vol. I, edited by K. Mendelssohn, *Academic Press, Inc.*, 259 pp., $11, 1959—A collection of papers covering the production, maintenance, and measurement of low temperatures and their practical application to the techniques used in basic research. Topics discussed include superconductivity circuits . . . thermoelectric cooling . . . distillation at low temperatures . . . frozen free radicals . . . low-temperature calorimetry . . . the determination of specific heats by the temperature-wave method . . . and the ultrasonic attenuation in metals at low temperature. •

Warmofen für Walzwerke und Schmieden, edited by Z. Wusatowski, *Verlag Technik*, 612 pp., approx. $10.40, 1959—This German collective work, originally published in Polish, deals with the design and operation of heating furnaces for rolling mills and forges. Both fuel-fired and electrical furnaces are covered, and the book also includes basic combustion theory, specialized aspects, and numerical examples of calculations. Extensively illustrated, the book emphasizes the practical side of the subject. •

Uranium Production Technology, by Charles D. Harrington and Archie E. Ruele, *D. Van Nostrand Co., Inc.*, 579 pp., $17.50, 1959—The technology used in producing high-purity uranium metal and compounds is discussed in this work. The major portion of the book deals with present-day production techniques and the ensuing fabrication methods of rolling, extrusion, forging, and machining. There are also separate chapters on the chemistry and metallurgy of uranium, uranium alloys . . .producing uranium hexafluoride . . .producing enriched compounds . . .new technology. . .and health hazard control. •

Proceedings of the Third Plansee Seminar on High-Melting Metals, edited by F. Benesovsky, *Lange & Springer*, Berlin, 465 pp., $11.65, 1959—This German-language volume recounts the 1958 seminar on high-melting metals. It is divided into six parts. The first deals with theoretical questions of sintering and high-melting; the second part takes up tungsten and tungsten alloys. The third section deals with molybdenum and molybdenum alloys, while parts four and five examine tantalum, columbium, and rarer metals such as rhenium and osmium and their alloys. The final part combines papers on metal-metal oxide materials. •

Physical and Engineering Properties of Materials for Nuclear Fuel Elements, compiled by Henry H. Hausner, *Sylvania-Corning Nuclear Corp.*, 55 pp. (paper), $1, 1959—This is a compendium of physical and engineering data about elements, alloys, compounds, and other materials of particular interest to those engaged in the design, fabrication, and use of nuclear fuel and control elements. Eighty tables are presented: the first contains thermal-neutron cross sections of 50 commonly available elements; succeeding ones give various physical and thermal properties of uranium (18 tables); uranium alloys (11); thorium (6); plutonium (5); ceramics (10); zirconium and Zircaloy-2 (10); aluminum (5); stainless steel (4); graphite (5); and other high-temperature materials (5).

Random Vibration, edited by Stephen H. Crandall, *John Wiley & Sons, Inc.*, 423 pp., $8.50, 1959—The material in this book is specifically addressed to engineers already familiar with the classical problem of mechanical vibration. New concepts required to extend ordinary vibration theory into the field of random vibration are described and a broad picture is given of the current state of the art of designing and testing equipment which must withstand random vibration. The book is divided into two parts, the first six chapters treating basic concepts and background material, while the latter six show applications to the problems of design and testing.

Material for the book was originally given during a summer program on random vibration given at the Massachusetts Institute of Technology in 1958. •

RESEARCH METALLURGISTS
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Advanced Technology Laboratories currently can offer a number of senior positions in connection with materials research and development programs in the nuclear field.

Opportunities exist for metallurgists to carry out both basic and applied research in connection with fuel element development programs. A number of interesting investigations are currently in progress covering the fields of mechanical metallurgy, alloy development, and ceramic fabrication techniques. Materials engineers are needed for several advanced reactor design projects.

Send resume, in confidence, to Dean W. Townsend, American-Standard, Advanced Technology Laboratories, 369 Whisman Road, Mountain View, California.

ADVANCED *Technology* LABORATORIES
A DIVISION OF AMERICAN-Standard

Response of Metals To High-Velocity Deformation

PRELIMINARY PROGRAM

Stanley Hotel, Estes Park, Colo. — July 11-12, 1960

SUNDAY, JULY 10

2:00 pm to 6:00 pm — **Registration, Lobby**

MONDAY, JULY 11

8:30 am to 12:00 noon — **Registration, Lobby**

9:00 am to 12:00 noon — **Session I**

Survey of Mechanisms Controlling Dislocation Motions Up to Relativistic Speeds:
Johannes Weertman, Northwestern University

On the Role of Dislocations in the Dynamic Behavior of Aluminum Under Impulsive Loading:
F. Hauser, J. Simmons, and J. E. Dorn, University of California

Instrumentation for High Speed Strain Measurement:
J. M. Krafft, Naval Research Laboratory

Effect of Grain Size, Rate of Strain, and Neutron Irradiation on the Tensile Strength of Steel:
J. D. Campbell, Oxford University

1:30 pm to 4:30 pm — **Session II**

Dynamic Stress and Deformation in a Mild Steel at Normal and Low Temperatures:
D. B. C. Taylor and L. E. Malvern, University of Cambridge

Crystallographic Aspects of High-Velocity Deformation of Aluminum Single Crystals:
R. B. Pond, Johns Hopkins University, and C. M. Glass, Aberdeen Proving Ground

Some Fundamental Properties of Shock Waves:
George E. Duvall, Stanford Research Institute

A Metallurgical Method for Simplifying the Determination of the Hugoniot Curves for Iron Alloys in the Two-Wave Region:
C. M. Fowler, F. S. Minshall, and E. G. Zukas, Los Alamos Scientific Laboratory

Chuckwagon Dinner

TUESDAY, JULY 12

9:00 am to 12:00 noon — **Session III**

Dynamic Response of Metals to Shock Waves:
S. Minshall, Los Alamos Scientific Laboratory

I—The Behavior of Iron and Steel Under Impulsive Loading; and
II—The Behavior of 0.45 and 1.0 pct. Carbon Steel Under Impulsive Loading:
E. G. Zukas and C. M. Fowler, Los Alamos Scientific Laboratory

Metallurgical Effects of High Intensity Shock Waves in Metals, I—BCC Metals; II—Nickel:
G. E. Dieter, E. I. du Pont de Nemours and Company

Shock Wave Effects on Austenitic Manganese Steel:
A. H. Holtzman and G. R. Cowan, E. I. du Pont de Nemours and Company

1:30 pm to 4:30 pm — **Session IV**

Further Metallographic Studies of Metals Subject to Explosive Shock:
C. S. Smith, University of Chicago, and C. M. Fowler, Los Alamos Scientific Laboratory

Effects of Explosive Loading on Single Crystals and Polycrystalline Aggregates:
C. M. Glass and G. L. Moss, Aberdeen Proving Ground

On the Fracture of Solids under Impulsive Loading Conditions:
J. L. O'Brien, Harvard University, and R. S. Davis, Arthur D. Little Company

General Information

The Physical Metallurgy Committee is one of eighteen technical committees in the Institute of Metals Division of The Metallurgical Society. The principal objective of the Committee is to provide means for the dissemination of information regarding the effects of structure on the properties of metals. This is accomplished by sponsoring separate technical conferences as well as technical sessions at the Fall Meeting of The Metallurgical Society and the Annual Meeting of AIME. Although all activities sponsored by the committee are open to the public, it is hoped that nonmembers of AIME who participate will be encouraged to investigate the additional benefits of membership in The Metallurgical Society of AIME, which is the professional society for metals men. It is only through the existence and support of the Society that such activities are possible.

Discussion of all papers given at the Conference is encouraged. However, you will be asked to submit a written summary of your remarks to insure their appearance in the bound Proceedings of the Conference.

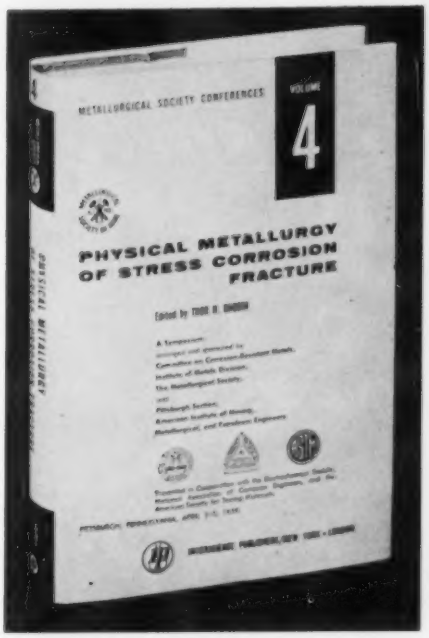
A copy of the Proceedings is included in the registration fee paid by each person attending the Conference. It is anticipated that you will receive your volume within seven to nine months after the meeting.

Hotel Reservations should be made on the enclosed form. The Stanley Hotel, which operates on the American Plan, has reserved part of its guest accommodations for conference registrants. These will be assigned in the order in which reservations are received. Information on alternate accomodations can be obtained by writing to:

Chamber of Commerce
Box 485
Estes Park, Colorado

Transportation. Estes Park is about 60 miles from Denver. If you are arriving by public transportation, please notify the Stanley of your time and place of arrival so that transportation to Estes Park can be arranged.

NEW Metallurgical Society Conferences



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a new series of books • uniform in format • each the proceedings of a technical conference sponsored by The Metallurgical Society of AIME through its technical committees • affording the rapid and coordinated publication of scientific and technical information • in books of high quality • in the form most useful to metallurgists everywhere • to cover the entire field of metallurgy

First in the series

1 Flat Rolled Products: Rolling and Treatment

Sponsored by the Mechanical Working Committee of the Iron and Steel Division, The Metallurgical Society and the Chicago Section of AIME. Chicago, January 21, 1959. Edited by T. E. DANCY and E. L. ROBINSON

148 pages, illustrated $3.75

2 Reactive Metals

Sponsored by the Niagara Frontier Section in cooperation with The Metallurgical Society of AIME. Buffalo, May 27-29, 1958. Edited by W. R. CLOUGH

624 pages, illustrated $15.00

3 Quality Requirements of Super-Duty Steels

Sponsored by the Physical Chemistry of Steelmaking Committee of the Iron and Steel Division, Institute of Metals Division, The Metallurgical Society and the Pittsburgh Section of AIME. Pittsburgh, May 5-6, 1958. Edited by R. W. LINDSAY

320 pages, illustrated $8.50

4 Physical Metallurgy of Stress Corrosion Fracture

Sponsored by the Corrosion-Resistant Metals Committee of the Institute of Metals Division, The Metallurgical Society and the Pittsburgh Section of AIME. Pittsburgh, April 2-3, 1959. Edited by T. N. RHODIN

408 pages, illustrated $13.00

Also to be published under the sponsorship of The Metallurgical Society of AIME

Extractive and Physical Metallurgy of Plutonium and Its Alloys

San Francisco, February 16-17, 1959. Edited by W. D. WILKINSON, Argonne National Laboratory

In press

Additional volumes, the Proceedings of recent and forthcoming Conferences, are in preparation

Physical Chemistry of Process Metallurgy

Pittsburgh, April 27-30, 1959. Edited by G. R. ST. PIERRE

Properties of Elemental and Compound Semiconductors

Boston, August 31-September 2, 1959. Edited by H. C. GATOS

Refractory Metals

Detroit, May 25-26, 1960

Response of Materials to High Velocity Deformation

Estes Park, Colorado, July 11-12, 1960

Other volumes to be announced

AIME members may purchase volumes in the Metallurgical Society Conferences series from the Society at a twenty per cent discount. (Registrants at these Conferences will receive a copy of that volume in the series as part of their registration fee.) Non-members may order direct from Interscience Publishers, Inc.

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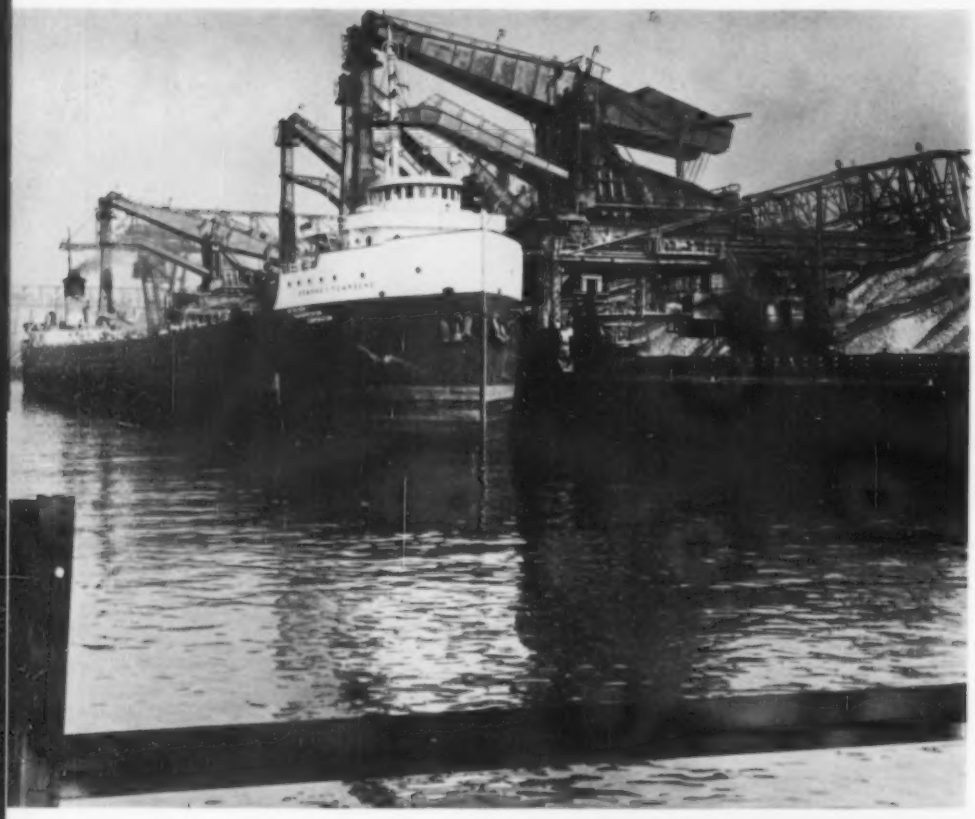
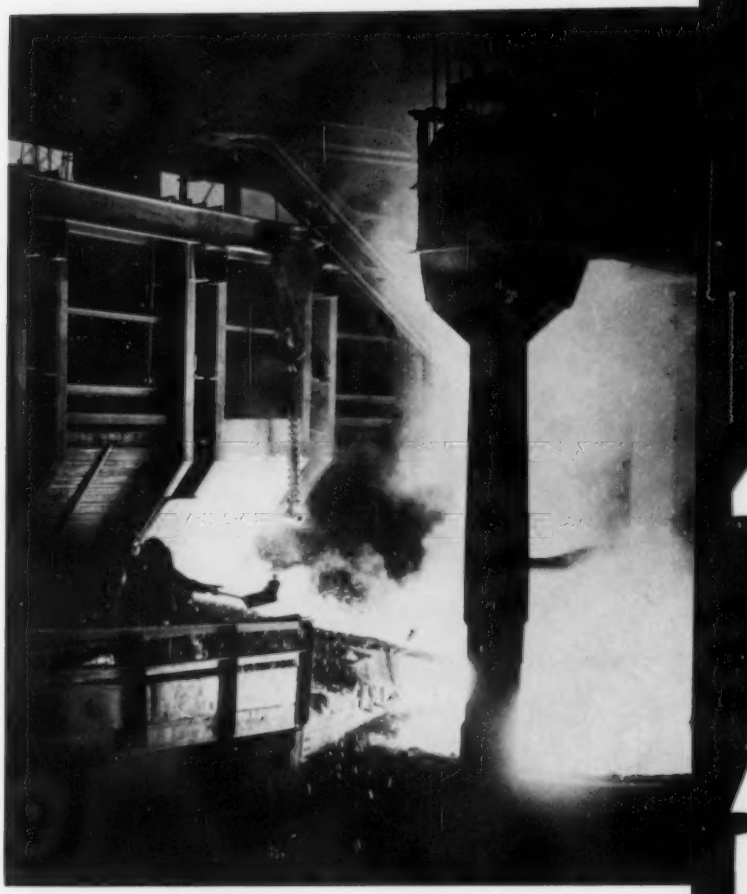


The Lackawanna plant of Bethlehem Steel Co. graciously opened its door to Journal of Metals' artist and photographer, David Cain.

Picture Story of Steelmaking

by

David Cain



A day as guest of Jones & Laughlin Steel Corp.'s Aliquippa works gave time to observe all aspects of open-hearth operations.

National Open Hearth Steel Committee's Local Section Reports

Southern Ohio Section

A record attendance of 215 hailed the start of Southern Ohio section's 1959-1960 meeting season on Oct. 16th. It was really a two-day meeting, with the Section's 23rd Annual Technical Conference being held at the Deshler-Hilton Hotel in Columbus on the 16th, and the Ohio State-Purdue football game on the 17th. A meeting of the Executive Board, National Open Hearth Steel Committee, was also held that day.

R. K. Thornberry, Acme-Newport Steel Co., Newport, Ky., and O. V. Ireland, Armco Steel Corp., Middletown, Ohio, were co-chairmen of the morning session which saw presentation of seven papers. A. H. Osborne, Armco International Corp., presented a paper on *The Steel Industry of Japan*. Papers on

W. W. BERGMANN

Armco Steel Corp.
Middletown, Ohio
Chairman
Southern Ohio
Section

operating problems were presented by R. L. Sigl, Detroit Steel Corp., Portsmouth, Ohio; L. Yoder, Armco Steel Corp., Middletown; T. J. Murray, Armco Steel, Ashland, Ky; J. R. McDermott, Armco Steel, Middletown; R. Kuhni, Acme-Newport; and Kenneth Ott, Detroit Steel, Portsmouth.

R. L. Lewry, Detroit Steel, Portsmouth; and T. J. Murray presided over the afternoon session on furnace practice. Papers on oxygen steelmaking processes were presented by C. J. Petry, Acme Steel Co.; and J. N. Albaugh, Jones & Laughlin Steel Corp., Aliquippa, Pa. *Oxygen in Open Hearth Furnaces* was the subject of a paper by A. L. Hodge, Linde Co., div. of Union Carbide Corp. Papers on basic roofs were presented by McBeth Sample, Armco Steel, Middletown; R. L. Lewry, Detroit Steel, Portsmouth, Ohio; and R. E. Over, M. H. Detrick Co., Chicago. (For the complete story of the meeting, see p. 852 of the December JOURNAL OF METALS).

Plans for 1960 include the annual golf outing at the Elks Country Club, Portsmouth, Ohio, June 3rd; and the 24th Annual Technical Conference at the Deshler-Hilton Hotel in Columbus Sept. 23-24.

Section officers are W. W. Bergmann, Chairman; and G. E. Brehm, Secretary-Treasurer.

M. E. NICKEL

International
Harvester Co.
Chicago, Ill.
Chairman
Chicago Section

Chicago Section

Spring and fall technical meetings and an annual golf outing comprise the Chicago section's activities for the 1959-1960 season. The 1959 spring meeting was held at Phil Smidt's Restaurant, Hammond, Ind., on May 4th. K. R. Mattson, Inland Steel Co., was chairman of the technical program, which highlighted a paper on *Automatic Firing Control of Open Hearth Furnaces*. The paper was presented by E. C. Rudolphy, South works, U. S. Steel Corp., Chicago.

The Section's 12th annual golf party was held at the Midlothian Country Club on Sept. 10th. Total attendance was 461, including a record-breaking 259 who played golf.

The Fall Technical Meeting was scheduled for Phil Smidt's on Oct. 5th, but was postponed because of the steel strike. The meeting was held on Jan. 11th of this year instead. Ray McCurdy, Republic Steel Corp., acted as Technical Chairman for the meeting, which had basic roof construction for its theme. F. R. Smith, Gary works, U. S. Steel Corp., led off the meeting with a *Progress Report on Basic Roofs in the Chicago District*. Robert Demeter, Youngstown Sheet & Tube Co.; Howard Lee, Inland Steel Co.; and William R. McLain, South works, U. S. Steel Corp., also contributed to the program.

Because the National Open Hearth Conference is scheduled for Chicago this April, the Section's annual Off-the-Record Meeting will not be held this year. The remaining 1960 schedule includes: Spring Technical Dinner Meeting, Phil Smidt's Restaurant, May 2nd; annual golf outing, Gleneagles Country Club, Sept. 1st; and the Fall Technical Dinner Meeting, Phil Smidt's, Oct. 3rd.

Section officers, serving until March 1961 are Melvin E. Nickel, Chairman; Albert M. Kroner, Vice Chairman; and William R. McLain, Secretary-Treasurer.

Pittsburgh Section

The Section's annual golf party last June 16th drew a total of 374 participants, 212 of whom wielded golf clubs. Altogether, 85 prizes were awarded by the Suppliers Committee.

The Section's second annual event, its Off-the-Record Meeting, was held at the Penn-Sheraton Hotel in Pittsburgh Nov. 6th. A total of 940 registered for the event, which featured separate all-day technical sessions by each of the constituent Pittsburgh groups: Institute of Metals Group, Mineral Industries Group, Petroleum Subsection, Coal Division, and the NOHC section.

R. M. Barnhart, 1959 Chairman of the Pittsburgh section, NOHC, was toastmaster at the Fellowship Dinner which was attended by 367 members and guests. (The complete story of the meeting appeared on p. 20 of the January issue).

The officers for 1959-1960 are E. E. McGinley,

E. E. McGINLEY

U. S. Steel Corp.
Braddock, Pa.
Chairman
Pittsburgh Section

Chairman; R. M. Barnhart, Past-Chairman; J. N. Albaugh, Vice Chairman; J. G. Bassett, Secretary; and J. H. Smith, Treasurer.

This year's spring golf party will be at the Mt. Lebanon Country Club on June 13th. The 15th annual Off-the-Record Meeting will be at the Penn-Sheraton Hotel Nov. 4th.

Southwestern Section

A total of 210 persons attended the Fall Meeting of the Southwestern section at Peoria, Ill., last Oct. 8-9. Oct. 8th was devoted to a tour of the Keystone Steel & Wire Co., when 140 men viewed the plant's new, unusually-designed 180-ton open hearth. Oct. 9th witnessed an all-day technical session, featuring papers on oxygen steel practices and basic roofs. The two-day meeting was concluded with a Suppliers-sponsored cocktail party and a Fellowship Dinner. A. H. Sommer, Keystone Steel & Wire, served as toastmaster for the event, with Charles Cullen of Charles Cullen & Associates delivering the dinner speech. The Section's most recent annual February meeting was on Feb. 12th. Two technical sessions, a luncheon, cocktail party, and Fellowship dinner made up the day. Talks on uptake areas, hot patching basic roofs, nondestructive testing techniques for preventive maintenance, cupola and oxygen process at Acme Steel Co., and Keystone Steel & Wire's new 180-ton open hearth comprised the technical program.

The *Globetrotters*, as the Section has nicknamed

L. D. YAGER

Laclede Steel Co.
Alton, Ill.
Chairman
Southwestern
Section

itself, live up to their name come Oct. 13-14, when the Sheraton-Dallas Hotel becomes the site of their Fall Meeting. Plans call for taking in the SMU-Rice football game, plus other entertainment. The Texas State Fair will also be going on then. It will not be all play, however, for a plant visit to the Lone Star Steel Co. is slated for Oct. 13th, and technical meetings will be housed in the Sheraton-Dallas on Oct. 14th.

Section officers are Levi D. Yager, Chairman; and Harry J. Hausner, Secretary-Treasurer.

H. W. CLARK

Ford Motor Co.
Detroit, Mich.
Chairman
Detroit Section

Detroit Section

A joint meeting with the Detroit section, AIME, was a feature of the Detroit, NOHC, 1959-1960 meeting season. A paper on *Ingot Surface Quality*, by John Orton, Steel Co. of Canada, brought out an attendance of 130. The NOHC section's annual golf party was held Sept. 23rd, with 70 turning out to wield drivers and putters, and a grand total of 165 on hand for dinner.

On March 21st of this year, another joint meeting was held with the AIME Detroit section. Subject of this meeting was *Degassing of Steel*. The annual golf party will again be held in September. Section officers are H. W. Clark, Chairman; Harold Moyer, Vice Chairman; B. H. Ramage, Secretary; and J. C. Brown, Treasurer.

(MORE ——►)

R. J. PROUT

U. S. Steel Corp.
Torrance, Calif.
Chairman
Western Section

Western Section

Leading off the Western Section's 1959-1960 meeting season was a technical program on Oct. 7th. Speaker of the evening was W. K. Mote, Columbia-Geneva Steel div., U. S. Steel Corp., who talked about *Industrial Minerals Used in the California Steel Industry.* The Section's second meeting was held Dec. 8th, when F. E. Van Voris, Union Carbide Metals Co., div. of Union Carbide Corp., addressed the group on *Ferro-Alloys Steelmaking in the Future.*

Jan. 27th marked the Section's first meeting of this year, with C. M. Kay of the Operating Committee on Steel Production, U. S. Steel Corp., speaking on *The Use of Oxygen in Open Hearth Furnaces.* The second meeting was March 16th, when William Story of the Institute of Scrap Iron and Steel discussed scrap and scrap preparation. On Apr. 20th the Western section will hold a meeting in conjunction with the Acid Converter and Basic Oxygen Steel Committee Meeting and the Southwest Metals and Minerals Conference. (See p. 162 of the February issue and pps. 139 and 140 of the March issue for additional information).

Current Section officers are R. J. Prout, Chairman; M. A. Thompson, Vice Chairman; and W. E. Whitehouse, Secretary-Treasurer.

C. E. MOYER

Republic Steel Corp.
Buffalo, N. Y.
Chairman
Buffalo Section

Buffalo Section

The Section's sixth annual golf party last May 21st drew a total of 150 registrants. A luncheon and cocktail party was provided by the Suppliers' Committee, and an annual banquet rounded out the full day's activities.

On Nov. 10th, the proponents of old and new steelmaking processes were pitted against one another during the Section's 10th Annual Fall Meeting at the Sheraton-Connaught Hotel in Hamilton, Ontario, Canada. A morning plant trip to Dominion Foundries and Steel Ltd—the oldest operating basic oxygen (LD) steel plant in the Western hemisphere—led off the meeting. A total of 257 registered for the meeting, 182 of whom attended the annual banquet which concluded festivities. Details are given on p. 58 of the January issue.

This year's schedule has the seventh annual golf party at the Wanakah Country Club on May 26th. On Nov. 15th, the Statler-Hilton Hotel in Buffalo will be host to the Section's 11th Annual Fall Meeting.

Officers for 1960 are C. E. Moyer, Chairman; R. M. Jordan, Vice Chairman; and H. A. Morlock, Secretary-Treasurer.

C. B. JENNI

General Steel
Castings Corp.
Eddystone, Pa.
Chairman
Eastern Section

Eastern Section

A plant trip to E. J. Lavino & Co. and W. H. Corson Inc., opened the Section's 1959-1960 meeting activity on June 15, 1959. The Section's third annual golf party followed up the plant visits. Following the summer vacation interim, members reconvened at the Warwick Hotel in Philadelphia Oct. 9th for the Section's 13th Annual Technical Conference.

A total of 298 persons took advantage of the work lull occasioned by the steel strike to attend the meeting. A full day of papers and panel discussion on pouring pit practices and open-hearth roofs generated enough heated discussion to raise the temperature of the already warm Warwick ballroom a few degrees. A more detailed description of the meeting is provided on p. 856 of the December issue.

On the 1960 meeting agenda are a plant trip to Phoenix Iron and Steel Co., Phoenixville, Pa., on June 20th, followed by the Section's annual golf party at the Plymouth Country Club, Plymouth Meeting, Pa. This year's 14th Annual Technical Conference on Oct. 21th, is again scheduled for the Warwick Hotel.

Section officers for 1960-1961 are Clyde B. Jenni, Chairman; R. Russell Fayles, Vice Chairman; Robert G. Waite, Secretary-Treasurer; Program Committee Chairman, J. Gardner Blythe; and Director members of the Executive Committee; Harry L. Tear and James T. Clisham.

Cleveland Section

Meeting attendance and membership continues to increase for the Section. A total of 105 couples attended the Section's Annual Dinner-Dance at the Lake Shore Hotel June 20, 1959. The 1959-1960 meeting season was reactivated on Nov. 12th with a technical meeting on *Pouring Pit Practice and Mold Preparation;* 82 persons attended. The subject of this year's first meeting was the *Effects of Prolonged Shutdown*. The Rockside Garden meeting drew an attendance of 73.

E. J. SOBEY

Jones & Laughlin Steel Corp.
Cleveland, Ohio
Chairman
Cleveland Section

Basic Oxygen Process and Use of Oxygen in Open Hearths was the topic of discussion at the Cleveland section meeting on March 17th. The meeting was also designated Suppliers' Night. On May 12th, the Section will feature a *Progress Report on Basic Roofs*. This year's Lake Shore Hotel Dinner-Dance will be on Saturday, June 18th. This festive occasion will mark the completion of the Section officers' two-year term of office. Present officers are E. J. Sobey, Chairman; E. G. Kondas, Vice Chairman; L. Svete, Secretary; and W. M. Nielsen, Treasurer. New officers will be elected in August.

"All meetings are of the panel type," explains Chairman Sobey. Melters, general foremen, pit foremen, metallurgists, and combustion department personnel are the principal speakers, he notes, and the lengthy discussion periods following the talks indicate the benefits derived by the attending members.

T. A. CLEARY, JR.

The Youngstown Sheet & Tube Co.
Youngstown, Ohio
Chairman
Northern Ohio Section

Northern Ohio Section

A record attendance of 337 took in the Northern Ohio section's 1959 Off-the-Record Meeting on March 12th. Al Hubbard of Youngstown Sheet & Tube Co., and K. Waggner of Republic Steel Corp. were co-chairmen of the meeting which featured the following papers: *LD Process*, by R. Edwards, Jones & Laughlin Steel Corp.; *Ingotrol* (Automatic weighing of teemed ingots), by R. Watson, Republic Steel Corp.; *Refractory Gunning for Open Hearth Furnace Maintenance*, by R. C. Oswald, Sharon Steel Corp.; *High Carbon Rimming Steels*, by John Beale, Republic Steel; and *Increased Open Hearth Production With the Use of Oxygen*, by T. A. Thompson, Weirton Steel Co. The after-dinner talk was given by William McKeon, Union Carbide Metals Service, on the subject: *Alloys for the Present and Future*.

On June 10, 1959, 266 attended the Section's annual golf party.

This year's Off-the-Record Meeting was held at the Hotel Pick-Ohio in Youngstown March 10th. The golf party is again scheduled for the Squaw Creek Country Club, this year on June 8th.

Section officers for 1960-1961 are T. A. Cleary, Jr., Chairman; and Jack R. McPhillips, Secretary-Treasurer.

Soviet Translation

Coke and Chemistry, USSR, is the title of the English translation of *Koks i Khimiya*. The translation is being made by The Coal Tar Research Association and The British Coke Research Association.

The Russian journal is designed for persons interested in coal carbonization for the production of metallurgical and gas coke, and in the recovery and refining of byproducts of coking.

The August 1959 issue is the first one being translated. Complimentary copies of this issue are available on request. The subscription rate for 12 monthly issues has been set at $16. For free initial copies or subscriptions, write: *The Librarian, The Coal Tar Research Association, Oxford Road, Gomersal, Leeds, England.*

Gas Determination Theme of London Meet

The Determination of Gases in Metals is the theme of a meeting to be held in London May 3-4. The Society for Analytical Chemistry, The Institute of Metals, and The Iron and Steel Institute are the meeting's joint sponsors.

Among contributors to the program we find the name of T. B. King of Massachusetts Institute of Technology. Dr. King is scheduled to give a paper on *Sampling of Liquid Metals*.

No registration fee is being charged for the meeting. But those wishing to attend are asked to immediately apply to *The Secretary, The Iron and Steel Institute, 4 Grosvenor Gardens, London, S. W. 1.*

Drop in Enrollments Bode Fewer Engineering Grads, ASEE Says

There will be fewer engineering graduates within the next one or two years, so warns the American Society for Engineering Education (ASEE). Though 1959 graduate figures showed a continued rise due to the influence of high enrollments in the mid-1950's, entering freshman classes have been getting smaller, the Society notes. Last fall, 240,063 students registered in engineering, the Society points out; in 1958 there were 249,950, and in the fall of 1957, 247,777. The figures are assembled each year under a joint ASEE-Office of Education survey.

Programs

National Open Hearth Steel Committee and Blast Furnace, Coke Oven, and Raw Materials Committee

The Palmer House, Chicago, will be the scene of the 43rd conference held April 4 through 6, 1960. Registration will be in the Ballroom Foyer 3 to 9 pm, Sunday, April 3; 8 am to 5 pm, Monday, April 4; 8 am to 5 pm, Tuesday, April 5; and 8 am to 4 pm, Wednesday, April 6. Special busses for the plant trip to Acme Steel Co., and Inland Steel Co., on Wednesday, April 6, will leave from the Palmer House.

NATIONAL OPEN HEARTH STEEL CONFERENCE

Monday, April 4

General Session

9:30 to 10:30 am—Grand Ballroom

Welcoming Remarks: *D. R. Loughrey*, Jones & Laughlin Steel Corp., and General Chairman, National Open Hearth Steel Committee, AIME

Announcements and Reports

McKune Award Paper

Basic Operations Session

10:30 am to 12:15 pm—Grand Ballroom

Chairmen: *G. L. Owens*, Vice President, Operations, Great Lakes Steel Corp. Ecorse, Detroit, Mich.

C. M. Kay, Assistant Chairman, Operating Committee, Steel Production, U. S. Steel Corp., Pittsburgh, Pa.

Steel Production With Safety: *F. R. Barnako*, Manager of Compensation and Safety, Bethlehem Steel Co., Bethlehem, Pa.

Discussion: *E. L. Wentz*, Division Superintendent, Steel Production, Ohio Works, U. S. Steel Corp., Youngstown, Ohio

P. F. Adams, Assistant to the Open Hearth Superintendent, Bethlehem Steel Co., Bethlehem, Pa.

George Grosvenor, Superintendent of Steel Production, Colorado Fuel and Iron Corp., Pueblo, Colo.

Steve Purcell, Open Hearth Superintendent, Lone Star Steel Co., Lone Star, Texas.

Monday, April 4

Acid Operations Session

10:30 am to 12:15 pm—Parlor 14

Chairman: *R. M. Barnhart*, Superintendent, Open Hearth, Alco Products Inc., Latrobe, Pa.

Practical Method for Statistical Evaluation of Open Hearth Problems: *R. A. Hinnebusch*, Chief Metallurgist, and *J. A. McKinnon*, Research Metallurgist, United Engineering and Foundry Co., Vandergrift, Pa.

Use of Ultrasonics in Testing for Steel Cleanliness: *A. C. Mager*, General Foreman-Open Hearth, Hepenstall Co., Pittsburgh, Pa.

Operating Metallurgy

2:00 to 5:00 pm—Grand Ballroom

Chairmen: *T. V. Wainwright*, Practice Engineer, Steelmaking, Bethlehem Steel Co., Bethlehem, Pa.

C. R. Taylor, Supervising Research Metallurgist, Research Laboratories, Armco Steel Corp., Middletown, Ohio.

A General Method for the Analysis of Plant Operating Data Using a Digital Computer Tied to a Study of an Open Hearth Furnace Using a Roof Lance: *A. P. Woods*, Senior Research Engineer, Armco Steel Corp. Middletown, Ohio

Monday, April 4

Discussion: *R. J. King*, Assistant Division Chief, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

D. C. McCune, Research and Development Department, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

F. G. Norris, Wheeling Steel Corp., Steubenville, Ohio

Metallurgical Aspects of Oxygen Roof Lancing: *F. E. Gribble*, Division Metallurgist, and *W. F. Zepfel*, Chief Process Metallurgist, Metallurgical Department, U. S. Steel Corp., Homestead, Pa.

Discussion: *T. B. Winkler*, Division Head, Research Department, Bethlehem Steel Co., Bethlehem, Pa.

Survey of the Operational Experience Gained Till Now With the Steel Degassing Process Developed by Dortmund-Harder Huttenunion: *F. Harders*, President, and *H. Knuppel*, Director of Research, and *K. Brotzmann* Dortmund-Horder Huttenunion *A. G.*, Dortmund, Germany.

Discussion: *F. C. Langenberg*, Chief Development Metallurgist, Crucible Steel Co. of America, Midland, Pa.

Open Hearth Refractories Session

2:00 to 5:00 pm—Venetian Room, Morrison Hotel

Chairmen: *A. K. Moore*, Superintendent, Open Hearths, The Steel Co. of Canada, Ltd. Hamilton, Ontario, Canada

C. N. Jewart, Ceramic Engineer, Bethlehem Steel Co. Lackawanna, N. Y.

Use of Chemically Bonded Hot Tops at Lukens: *D. E. Grimme*, Assistant to Superintendent of Refractories and Fuels, and *D. K. Matthews*, Foreman of Hot Tops, Lukens Steel Corp., Coatesville, Pa.

Report on Low-Pressure Roof at Sharon Steel Corp.: *J. W. Flowers*, Masonry Superintendent, Sharon Steel Corp., Sharon, Pa.

Progress Report on Carbon Sub-Hearth Installation: *J. E. Smith*, Superintendent, Open Hearths, Republic Steel Corp., Warren, Ohio.

Experience With the Maerz-Boelens Furnace: *A. H. Sommer*, Vice-President and General Superintendent, Keystone Steel and Wire Co., Peoria, Ill.

Tuesday, April 5

Basic Oxygen Furnace Operating Session

9:30 am to 12:15 pm—Grand Ballroom

Chairmen: *A. A. Kappenhagen*, General Superintendent, Republic Steel Corp., South Chicago, Ill.

George Grosvenor, Superintendent of Steel Production, Colorado Fuel and Iron Co., Pueblo, Colo.

Experience in Production of High, Medium, and Low-Carbon Steels: *C. C. Benton*, Division Superintendent, Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario, Canada.

Basic Problems Encountered in Handling Materials and Products: *J. N. Albaugh*, Superintendent Steel Works, Jones & Laughlin Steel Corp., Aliquippa, Pa.

Tuesday, April 5, Continued

Basic Oxygen Furnace With Cupola Iron: *E. M. Richards*, Director of Iron and Steel Producing Division, Acme Steel Co., Riverside, Ill.

Operating and Combustion Session

9:30 am to 12:15 pm—Parlor 14

Chairmen: *A. T. Hubbard*, Superintendent, Open Hearth, Brier Hill Works, Youngstown Sheet and Tube Co., Youngstown, Ohio

P. T. Nutting, Superintendent, No. 1 Open Hearth, Inland Steel Co. East Chicago, Indiana.

Production Advantages From the Use of Oxygen Roof Lances: *Orville O. Haniford*, Superintendent, No. 5 Open Hearth, U. S. Steel Corp., Gary, Indiana

Discussion: *H. W. Clark*, General Superintendent, Open Hearth and Electric Furnaces Steel Division, Ford Motor Company, Michigan

Refractory Problems Resulting from the Use of Oxygen Roof Lances: *W. J. Scharfenaker*, Assistant Open Hearth Superintendent, Great Lakes Steel Corp., Ecorse, Detroit, Michigan

Discussion: *R. N. Ames*, General Supervisor, Ceramic Development, U. S. Steel Corp., South Works, Chicago, Illinois.

Design Problems—Oxygen Roof Lances: *E. J. Sobey*, Assistant Open Hearth Superintendent, Jones & Laughlin Steel Corp., Cleveland, Ohio.

Discussion: *Don Nelson*, Assistant Superintendent, No. 3 Open Hearth, Inland Steel Company, East Chicago, Indiana

Fuel and Firing Practices With Oxygen Roof Lances: *L. T. Sanchez*, Superintendent, Open Hearth, Lorain Works, National Tube Division, U. S. Steel Corp., Lorain, Ohio

Basic Oxygen Furnace Refractories Session

2:00 to 5:00 pm—Grand Ballroom

Chairman: *J. R. Atkinson*, Dominion Foundry and Steel Co., Hamilton, Ontario, Canada

Furnace Linings: *E. M. Richards*, Director of Iron and Steel Producing Division, Acme Steel Co., Riverside, Ill.

Discussion: *F. C. Muttitt*, Assistant Superintendent Masonry, Algoma Steel Corp., Sault Ste. Marie, Ontario, Canada.

Ladle Lining Practice for Basic Oxygen Steel: *B. L. Dorsey*, Refractories Engineers, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Annual Fellowship Dinner

Tuesday, April 5

6:30 pm—Exhibit Hall

Reception and Cocktail Party for dinner guests

7:00 pm—Grand Ballroom

Annual Fellowship Dinner

Toastmaster: *Edward C. Logelin*, Vice President, U. S. Steel Corp., Chicago, Ill.

Speaker: *James C. Downs, Jr.*, Chairman of Board, Real Estate Research Corp., Chicago, Ill.

Programs

BLAST FURNACE, COKE OVEN, AND RAW MATERIALS CONFERENCE

Monday, April 4

Blast Furnace Practice Session

9:00 am to 12:15 pm—Red Lacquer Room

Chairmen: *R. A. Dise*, Assistant to Div. Supt., Central Furnaces and Docks, American Steel and Wire Div., U. S. Steel Corp., Cleveland, Ohio

J. L. Johnson, Director, Planning and Development, Interlake Iron Corp., Cleveland, Ohio

Technology of Carbonaceous Blast-Furnace Tap Hole and Through Mixes: *G. R. Eusner*, Division Chief, and *J. T. Shapland*, Ceramic Engineer, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Design, Construction, and Operating Features of a New Merchant Blast Furnace Plant: *W. N. Nielsen*, Superintendent, No. 5 Blast Furnace Plant, U. S. Pipe and Foundry Co., Birmingham, Alabama.

Automatically Charged Blast Furnaces Become a Reality: *Raymond Erbe*, Westinghouse Electric Corp.

Nuclear Stockline Gage For Blast Furnaces: *L. R. Stone*, Head, Nucleonics Div., Electromechanical Research Center, Republic Steel Corp., Cleveland, Ohio.

Coal Session

9:00 am to 12:15 pm—Room 18

Chairmen: *J. R. Dietz*, Senior Research Engineer, National Steel Corporation, Weirton, West Virginia

W. H. Mathews, Manager Coke Production, Inland Steel Co., East Chicago, Ind.

The Use of Coal Plasticity in Coke Plant Coal Blending: *W. G. Schulze*, Superintendent, Coke and Coal Chemical Plant, and *G. C. Soth*, Coke Plant Chemist, Fontana Works, Kaiser Steel Corp., Fontana, California.

Fine Coal Cleaning with the Circular Concentrator Table: *H. B. Charmbury*, Head, Department of Mineral Preparation, Pennsylvania State University, University Park, Pa.

Nature of Coking Coals and the Mechanism of Coke Formation: *N. Berkowitz*, Chemist in Charge, Coal Research Division, Research Council of Alberta, Edmonton, Alberta, Canada.

Technical and Economic Effects of Moisture in Coking Coals: *J. D. Doherty*, Consulting Engineer, Island Creek Coal Co., Huntington, W. Va., and *J. Griffen*, Coal and Coke Consultant, Pittsburgh, Pa.

Monday, April 4

Iron Ore Reduction Session

9:00 am to 12:15 pm—Wabash Room

Chairmen: *H. U. Ross*, Prof. of Metallurgical Engineering, University of Toronto, Toronto, Ontario, Canada

G. G. Hatch, President, W. S. Atkins and Assoc. Ltd., Toronto, Ontario, Canada

The Alan Wood H-Iron Plant: *R. A. Lubker*, Director of Research and Development, Alan Wood Steel Co., Conshohocken, Pennsylvania.

Thermodynamics of Direct Reduction Processes: *Kun Li*, Research Associate, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Kinetics of Hydrogen Reduction of Hematite: *W. A. Hockings*, Research Engineer, Institute of Mineral Research, The Michigan College of Mining and Technology, Houghton, Michigan.

Study of the Kinetics of Magnetic Roasting: *J. P. Hansen*, Research Metallurgist, Bureau of Mines, Minneapolis, Minnesota, *G. Bitsianes*, and *T. L. Joseph*, Dept., of Metallurgical Engineering, University of Minnesota, Minneapolis, Minnesota.

Direct Reduction of Fine Iron Concentrates in a Self-Agglomerating Fluidized Bed: *B. Langston*, Assistant Division Chief, and *F. M. Stephens*, Division Chief, Extractive Metallurgy Div., Battelle Memorial Institute, Columbus, Ohio.

Blast Furnace Theory Session

2:00 to 5:00 pm—Red Lacquer Room

Chairmen: *W. F. Luerssen*, Chief Research Engineer, Inland Steel Co., East Chicago, Indiana

W. E. Marshall, Research and Development, Armco Steel Corp., Middletown, Ohio

Predicting Blast Furnace Performance from Operating and Thermal Data: *H. N. Lander, H. W. Meyer, F. D. Delve*, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Monday, April 4

Injection of Different Materials in the Blast: *J. A. Cordier*, Head, Blast Furnace Research Section, Institut de Recherches de la Siderurgie, St. Germain-en-Laye, France.

Investigations on the Enrichment of Blast Furnace Air: *N. B. Melcher*, Research Director, Minneapolis Metallurgical Research Center, U. S. Bureau of Mines, Minneapolis, Minn. and *G. H. Kesler*, Associate Director, Basic Research, National Steel Corp., Weirton, West Va.

Results of Research Carried Out in 1959 at the International Low-Shaft Blast Furnace—Fuel Oil and Gas Injection: *M. L. Halbrecq* and *E. P. Bonnaure*, Institut de Recherches de la Siderurgie, St. Germain-en-Laye, France.

Coke Session

2:00 to 5:00 pm—Room 18

Chairmen: *H. E. Harris*, Assistant Manager, Research Laboratory, Eastern Gas and Fuel Associates, Boston, Massachusetts

G. W. Lee, Director, The British Coke Research Assoc., Chesterfield, Derbyshire, England

Recent Developments in British Coal Carbonization Research: *G. W. Lee*, Director, The British Coke Research Association, Chesterfield, Derbyshire, England.

Coking Pressure and Its Measurement-Current Theory and Practice: *H. E. Harris*, Assistant Manager Research Laboratory, *Wm. L. Glowacki*, Assistant Director of Research, and *John Mitchell*, Director of Research, Eastern Gas and Fuel Associates, Boston, Mass.

Operation of a Light Oil Extraction Dephenolizing Plant With Contact Towers: *J. D. Crane*, Assistant General Foreman, Coal Chemicals Department, Donner-Hanna Coke Corp., Buffalo, New York.

Repair of Oven Floors in Coke Battery No. 1 of the Brazilian National Steel Company, Volta Redonda, Brazil: *W. Motta*, Superintendent, Coke Plant, Brazilian National Steel Co., Volta Redonda, Brazil.

Tuesday, April 5

Sintering Session

9:00 am to 12:15 pm—Red Lacquer Room

Chairmen: *R. D. Burlingame*, Supervisor, Process Metallurgy Research, Malleable Research and Development Foundation, Dayton, Ohio

W. R. Kiessel, Manager, Applied Research Department, Steel Division, Ford Motor Co., Dearborn, Mich.

Use of Preheated Air in Sintering: *D. F. Ball*, and *J. M. Ridgiom*, Imperial College of Science and Technology, British Iron and Steel Research Association, London, England.

Sinter Plant Controls: *A. McDonough*, Division Superintendent of Blast Furnaces, South Works, U. S. Steel Corp., Chicago, Ill.

Tuesday, April 5, (Continued)

Calcium Ferrites in Relation to the Sintering of Iron Ores: *K. P. Hass*, Research Engineer, National Steel Corp., Weirton, W. Va., and *G. Bitsianes* and *T. L. Joseph*, Department of Metallurgical Engineering, University of Minnesota, Minneapolis, Minn.

A Dilatometer Investigation Into the Sintering of Iron Ores: *H. U. Ross*, Associate Professor of Metallurgical Engineering, University of Toronto, *B. A. Strathdee*, Research Engineer, Dominion Foundries and Steel Ltd., Hamilton, Ontario, Canada, and *J. E. Pierdon*, International Business Machines Co., Ltd., Toronto, Ontario, Canada.

Sintering Characteristics of Wabush Specular Hematite: *K. E. Merklin*, Chief Metallurgist, Hibbing Laboratory, and *F. D. DeVaney*, Director of Metallurgy and Research, The Pickands Mather & Co., Duluth, Minnesota.

Coal Chemicals Session

9:00 am to 12:15 pm—Room 18

Chairmen: *E. V. Schulte*, Assistant Manager, Development Department, Engineering and Construction Div., Koppers Co., Pittsburgh, Pa.

F. C. Lauer, Assistant Superintendent, Coke and Byproduct Department, Pittsburgh Works, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Coal Chemical Recovery and Processing Operations at the Youngstown Plant of Republic Steel Corporation: *R. E. Conn*, General Foreman, *C. R. Liphart*, Assistant General Foreman, Youngstown District, Republic Steel Corp., Youngstown, Ohio.

Optimum Operation in the Recovery of Light Oil: *Y. C. Chang*, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Coke Oven Gas Separation by Means of Low Temperatures: *H. F. Funk*, Representative, German Linde Corp., Toronto, Ontario, Canada

Removal of Anhydrous Ammonia From Coke Oven Gas: *M. O. Holowaty*, Chief Research Engineer,

(Continued on next page)

Annual Luncheon and Business Meeting, Blast Furnace, Coke Oven, and Raw Materials Committee

Tuesday, April 5

12:30 pm—Crystal Room

R. E. Powers, Chairman

Everyone attending the Blast Furnace, Coke Oven, and Raw Materials Conference is invited to attend this luncheon and annual business meeting.

(Tickets $4.00, tips and tax included)

Suppliers who have parlors for entertaining have been requested and are anxious to cooperate in closing their rooms during technical sessions and the dinner on Tuesday. Please help them cooperate by voluntarily leaving or avoiding their rooms at these times.

The Symbol of Modern Steel Men

Identifying modern steel men as professional metals men is the seal of The Metallurgical Society of AIME. Such men count on the services of the Iron and Steel Division of the Society to help them in their professional and personal development. Society services include such well established meetings as the Open Hearth and Blast Furnace Conferences as well as a variety of other gatherings and publications in response to members' needs.

The Metallurgical Society of AIME serves metals men engaged in extracting, refining, and fabricating metals, in metallurgical research, and in the development and application of metals and alloys. More than 7,000 members insure their own development while discharging their professional obligation by supporting the organization that fosters their best interests. Use the coupon below to learn more about The Metallurgical Society.

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Name _____

Address _____

Tuesday, April 5, Continued

Raw Materials and Reduction, *H. L. Taylor*, Chief Research Engineer, Research-Development Services, Inland Steel Co., East Chicago, Ind.

Computer Simulation Session

9:00 am to 12:15 pm—Room 17

Chairmen: *R. L. Wiegel*, Research Engineer, Jones and Laughlin Steel Corp., Pittsburgh, Pa.

J. B. Wagstaff, Fundamental Research Laboratory, United States Steel Corp., Monroeville, Pa.

An Analysis of Blast Furnace Stove Performance Using Special Temperature Measurements: *H. W. Meyer, N. F. Simcic, W. H. Ceckler*, and *H. N. Lander*, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Direct Analog Computer for Thermal Problems in Blast Furnaces and Coke Ovens: *V. Paschkis*, Director of Heat and Mass Flow Analyzer Laboratory, Columbia University, New York, N. Y.

Computer Study of the Kinetics of Reduction of Iron Ore in a Fluidized Bed: *E. C. Su*, Research Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Joint Session

2:00 to 5:00 pm—Red Lacquer Room

Chairmen: *D. C. Brown*, Assistant Director of Research, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Development of the Zonguldak Coal Field in Turkey, (Sound Motion Picture): *R. E. Zimmerman*, Vice President, Paul Weir Co., Chicago, Ill.

The High Temperature Evaluation of Blast Furnace Coke: *J. Varga, Jr.*, Project Leader, Process Metallurgy Research, Battelle Institute, Columbus, Ohio.

Hot Blast Water-Cooled Cupola as Applied to Steelmaking: *J. E. Rehder*, Vice President, Technology, Canada Iron Foundries Ltd., Montreal, Quebec, Canada.

Status of the Hot Cupola in The Steel Industry: *S. T. Jawinski*, Director of Research, Phoenix Steel Corp., Harrisburg, Pa.

1959 Proceedings: The 1959 PROCEEDINGS of both the Open Hearth and Blast Furnace, Coke Oven, and Raw Materials Conferences will soon be available. These and other available earlier bound volumes may be obtained by AIME Member past registrants at a 30 pct discount below the $10 price to the public.

Past Registrants of the
Blast Furnace, Coke Oven and
Raw Materials Conference, AIME

You are entitled to purchase, at this time and at the special rate, the following available volumes of the Proceedings of the Blast Furnace, Coke Oven, and Raw Materials Conference at $7.00 per volume ($10.00 to nonregistrants).

Volume 17 (1958)
Volume 16 (1957)
Volume 10 (1951)

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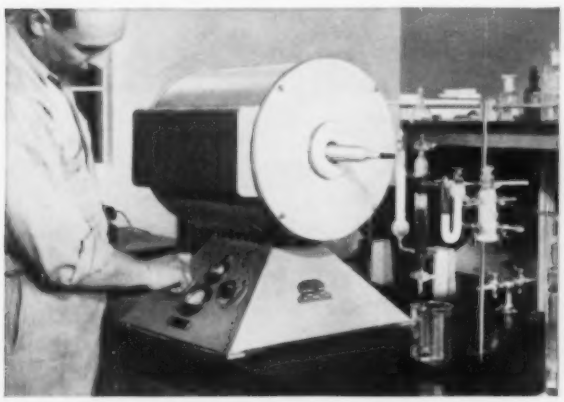
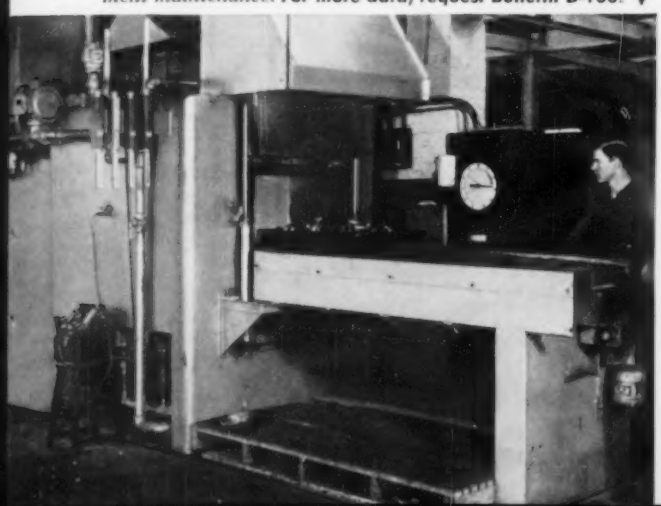
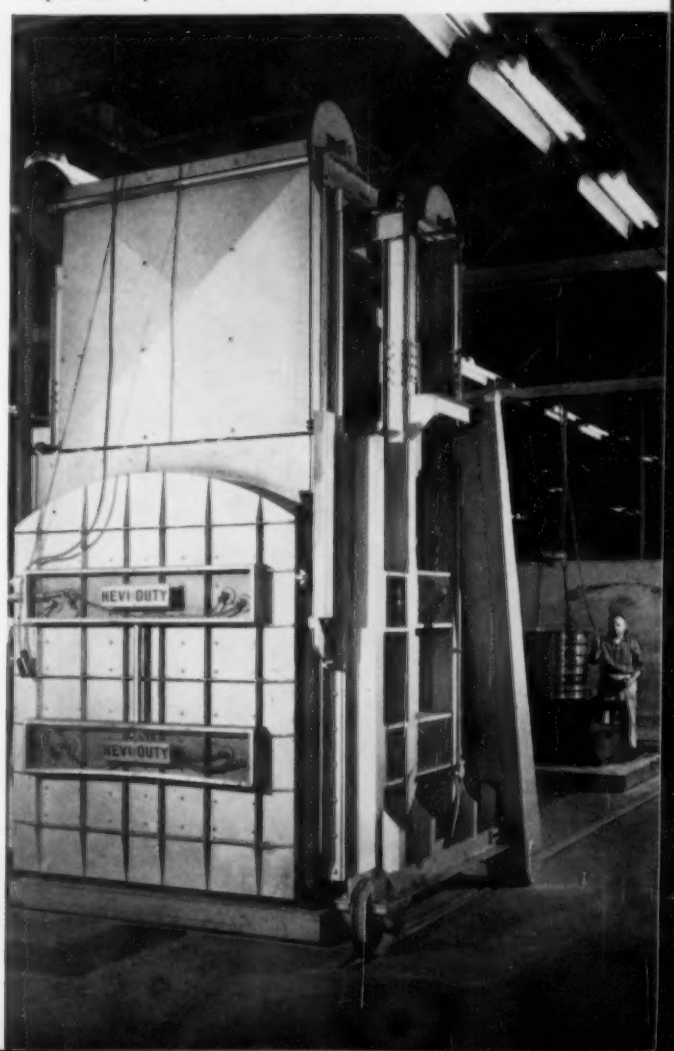


▲ *Merit Corp., Milwaukee, Wis., uses a Hevi-Duty tube furnace to maintain precise temperatures in laboratory quality tests on briquettes used by foundries as an additive to gray iron melts. Two-stage combustion operation on crushed sample burns off free carbon at 1679°F, total carbon at 2471°F.* **For more complete information, please write for Bulletin 254.**

Superior Metal Treating Corp., Muncie, Ind., uses two Hevi-Duty automatic Clean-Line furnaces 24 hours a day, 5 days a week for carburizing, carbonitriding and bright hardening. Temperatures range to 1925°F. The load-transfer mechanism is outside the heating chamber, reducing equipment maintenance. **For more data, request Bulletin D-100.** ▼



This Hevi-Duty traveling, double-end, box furnace provides ±10°F control at temperatures to 1850°F for bright tempering and stress relieving stainless steel jet engine weldments. This furnace is in continuous operation. User reports brightness improves during process. Unit provides bell-furnace mobility despite lack of head room. **Please write for Bulletin 653.** ▼



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QUO VADIS BLAST FURNACE ?

Photograph by David Cain at Lackawanna plant of Bethlehem Steel Co.

What is the future of the blast furnace? This essentially depends on us, on our attitude, and on our determination to get the most out of what we have and know.

by Michael O. Holowaty and James B. Austin

There are those among us who view the blast furnace with skepticism and would like very much to replace it with a more economical unit. This in itself is nothing new, since attempts of this kind have been made off and on since 1854. The accelerated pace of activity in studying other reduction processes during the last two decades is understandable and commendable, since increases in the rate of steel production require additional iron capacity, in the face of steadily mounting capital costs.

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Thus, in the first order it is the hope of reducing capital requirements which gives impetus to non-blast furnace reduction processes and schemes. But there are obviously also other factors which stimulate this work.

Direct reduction processes now under consideration fall into one of several categories with respect to the reducing medium and the qualities of the final product (liquid metal or solid scrap substitute). But all of these processes are expected to operate with low-quality solid fuels or gases, which at the present time are relatively inexpensive. Thus, their common denominator is the elimination of the coking facilities which are costly to construct and operate, since they are technologically fairly ineffi-

cient. Justification for their existence is based entirely on the fundamental characteristics of the modern blast furnace, which requires carbonaceous fuel of the highest quality with respect to chemical properties and to handling and performance at low and high temperature.[1] In order to achieve this we construct coke batteries whose only purpose is to transform brittle and semi-volatile bituminous coal into physically-stable, yet chemically highly-reactive coke.

Obviously the coke men will point out that, besides coke, the batteries also produce gas and chemicals as valuable byproducts. But how valuable? It appears that the fractional values of market realization for the byproducts obtained from each ton of coal have been decreasing steadily over the last 10 to 15 years. This is easily substantiated by the desire of many American coke producers to find ways of producing less ammonia, naphthalene, phenols, and so on, or to discontinue the production of these products entirely. Only 20 years ago the trend was exactly opposite.

Despite all shortcomings of the conventional coking process, we must admit that it is reliable and that it produces the only fuel which can be used successfully in the existing blast-furnace process.

If the high cost of coke is the major obstacle to the iron smelting in the blast furnace, we can proceed to change the situation along two separate paths:

a) Reduce the cost of coke or the coke rate per ton of iron ore, preferably both; and
b) Find an inexpensive substitute for metallurgical coke.

Lowering fuel costs

This problem is already under heavy attack from all sides, and the coke rates are dwindling very rapidly with substantial increases in the blast furnace productivity. Preparation of the burden, conditioning of the blast, high top-pressure, high-temperature blast, and other factors have contributed substantially to a reduction of the coke rate of the American furnaces which, in the last 20 years, dropped from an average of approximately 1970 lb to less than 1700 lb per ton in 1958. In making up the average figures, we should remember that even today there are furnaces whose coke rates exceed 2000 lb per ton of metal produced. Yet several furnaces, operating on highly beneficiated burdens, have already reached the low coke rates of 1200 lb and less. Even this cannot be considered the minimum which might eventually be attained. Injection of gaseous or liquid fuels through the tuyeres, addition of oxygen to the blast, and probably several other factors will help to bring the rate of coke containing 6 to 9 pct ash down to around 1100 lb per ton of metal produced.

Another way still open to us is the modification of the coking process itself. It appears entirely logical that great economy could be achieved by converting the present batch coking process to a continuous one. Many ideas in this field have been advanced in the past, but not many of them have been thoroughly investigated or explored. We have not even changed the cycle of metallurgical coke production in the 50 years of its existence, nor have we done much to increase substantially the capacity of the coking ovens—which obviously could be done without insurmountable difficulties.

The problem of finding a substitute for metallurgical coke has not proved to be an easy one. The ideas advanced in this field are limited to processes of charring, ferro-coke production, and the use of non-volatile fuels such as anthracite. None of these was ever successful even on the very modest scale of the so-called low-shaft blast furnace. Recent investigations of high-temperature properties indicate clearly that high-quality coke is the only fuel which can meet the rigid requirement of the furnace. With the coke rates decreasing, the problem of quality will grow more important than ever before.

Iron burden and fluxes

If a blast furnace operator of some 25 years ago would show up today at his own plant, chances are he would not recognize it, and, more, he would not be in full agreement with what we have done or are now doing. However, his particular interest, and maybe scorn, would go to the burden bins where he would find a material he did not respect or cherish —sinter. Only 25 years ago the mere presence of sinter was regarded as a nuisance with which to contend in order to get rid of flue dust. If he were to cast his look on a pile of the round iron-ore pellets, his only feeling would be that the new fellows have lost their minds. For instead of using regular *honest to goodness* ores, they are charging marbles. But he would be definitely pleased with the analysis of the ore burden which in his day of 1925 was beginning to show definite signs of deterioration. This was regarded as the unavoidable future prospect of the blast furnace operations. Yet this trend, which he considered as certain, has been reversed completely within a short span of one generation.

Changes in ore preparation and composition are finding counterparts in the preparation of the blast-furnace flux, which at the present time is also undergoing a major change. In the past, this limestone varied from 1 in. to as large as 6 in. and more. The present trend is to produce limestone fines classified as particles which pass ¼-in. or preferably ⅛-in screens. The reason for this change is that such limestone flux does not enter the shaft of the furnace in its original consistency, but is incorporated into the sinter feed and, thus, does not require the coarse size in order to support itself on the upper part of the burden column.

Future

Activity in direct reduction shifted into high gear some 10 years ago. Many processes and schemes have been developed and proposed, and some of them experimentally evaluated. Yet, in spite of the activity and pressure, not one of these processes has been applied on any large scale by the American steel industry up to this time.

What is the future of the blast furnace? This essentially depends on us, on our attitude, and on our determination to get the most out of what we have and know. The latter is unquestionably most important, since knowledge of the reduction processes in general and the blast-furnace process in particular provides an excellent basis for progress in the science of blast-furnace operation. It is this technology that is being currently applied to the design and development of various direct processes, and it would be definitely worthwhile to adapt or re-adapt

some of these factors to blast-furnace operations in order to achieve maximum efficiency. We would like to point out two recent papers which serve as guides: one by C. M. Squarcy and R. J. Wilson,[2] the other by J. M. Stapleton.[3]

The Burden Problem

The blast-furnace process is a chemical process and, as such, requires feed of extreme uniformity in respect to both the physical and the chemical properties. The ideal charge should consist of only a metallic burden fraction, carrying slagging or fluxing agents and the fuel fraction.

To maintain the uniformity of the stock column, it will be necessary to eliminate formation of layers in the furnace by thoroughly premixing the burden material. A further improvement would be achieved by replacing skip charging with continuous charging of the furnaces from the top. This obviously would necessitate redesigning the upper part of the furnace, but many parts of this vital area are not only costly but also obsolete.

Furnace Design

The change of the furnace feed suggests also that we should take another look at furnace design. The desirability and advisability of maintaining the present contour lines appears to be at least questionable. In the designing of the stack, it is necessary to compensate for the volume increase of the stock which reaches its maximum between 1550° and 1850°F. Following this, the volume of the stock is reduced rather quickly and some drastic change in the basic design might prove to be advantageous.

Refractories

A change in design might make it feasible to apply castable refractories instead of the conventional preshaped products. We readily admit that in this field we have done very little, but even our present knowledge indicates that between 30 to 40 pct of the total refractories in existing furnaces could be prepared in this manner. If this could be applied, the economy picture of the blast furnace would brighten considerably.

The Blast

The problem of the blast is an extremely important one since it involves actually both the chemistry and the operational conditions of the blast furnace process. Some of the factors involved are as follows:

a) Temperature of the blast should be held as high as possible. Since the present blast stoves set definite limits on any operation, it might be advisable to inject liquid or gaseous fuels into the tuyeres. The loss of oxygen incurring in this operation could easily be compensated by a slight increase of the oxygen content of the blast reaching the bustle pipe.

b) Oxygen enrichment is still another step to intensify the process of iron smelting. The volume or percentage of oxygen addition will depend on many factors, but in almost all cases it will require a compensating amount of steam in order to control the temperature of the race zones in front of the tuyeres. The increase of the carbon monoxide and hydrogen content of the gases moving upward in the shaft of the furnace will increase the intensity of the production rate of metal and lower the volume and the temperature of the top gases. The maximum fraction of oxygen permissible is difficult to assess, and estimates range from the enrichment figures of 25 pct total oxygen content of the blast to as high as 35 pct.

c) High top pressure is beneficial in all ranges, theoretically, the higher the better. Mechanical problems may eventually limit the top pressure to about 25 to 30 psi. It should be realized that the investigations in this field will be costly and time consuming. The major problem will be presented by the need to change the present blowers, most of which cannot work on top pressures exceeding 10 to 15 psi.

d) Tuyere design and blast distribution also fall into the scope of future changes and may well prove to be important. Various studies, carried out in the past, seem to indicate that the number of tuyeres could be increased and their size decreased to provide a more even blast distribution and deeper penetration into the stock column. This, however, remains to be proven.

Metal Casting

The system of metal casting and furnace operation might also require some serious thoughts. It is, for instance, conceivable that we might want to consider continuous casting of the furnace metal and, thus, eliminate the need for plugging and unplugging the tap hole. This arrangement might provide additional advantages, such as continuous desulfurization or desiliconization. Should this be economically feasible, we would be freed from the requirement of maintaining a specific minimum slag volume to effect desulfurization in the furnace itself. This ideal, however, belongs to the realm of research.

Research

The basic problem in the field of research is to establish first of all which of the two main fields, blast furnace or non-blast furnace, deserves more research in the immediate future. In making this decision, it is important to bear in mind that we have the blast furnaces, that we use them, and that almost all of them could produce considerably more than they do at the present time.

Many problems have been solved in the past by the steel industry, or by other related industries, but some remaining problems have not been tackled. The solution of these problems will be dictated by the geographic location, the available raw materials, and the requirements of a given plant or organization.

However, the need for some basic, creative thinking and large-scale experimentation is essential and should be accelerated and intensified as much as possible. Since all of the outstanding problems cannot be solved by one series of tests in one plant or company, the efforts might, and probably will, come from all branches of the American steel industry.

Eventually, as the picture unfolds, we will find that our blast furnaces, when properly equipped, can yield much more than was originally thought possible and that the blast furnace will dominate the steel plant scene for many years to come.

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SELF-AGGLOMERATING FLUIDIZED-BED REDUCTION

Is it an answer to the economic treatment of fine iron concentrates produced from low-grade ores?

by B. G. Langston and F. M. Stephens, Jr.

LOW-GRADE iron-ore deposits in Michigan and Minnesota provide the US with a large potential source of iron. To permit utilization, these resources required the development of an efficient system to beneficiate the ore to a grade sufficiently high for the concentrates to be used economically. Because of their mineralogical texture, both the jaspers in Michigan and the taconites in Minnesota require fine grinding to liberate the iron values. Having developed the beneficiation procedures needed to produce a concentrate of an acceptable grade, the metallurgist was still faced with an agglomeration step to produce a product which has a size acceptable to the iron and steel industry. For the production of iron in a blast furnace, the application of pelletizing and sintering procedures has given a satisfactory but somewhat costly answer to this problem.

It has long been recognized that the fine particle size of a concentrate would be an advantage in obtaining high rates of reduction to metallic iron; hence, agglomeration by pelletizing and sintering or by sintering of the fine concentrate is, to a certain extent, a step in the wrong direction. Thus, if equipment could be designed to take advantage of the fine particle size and, at the same time, directly convert large tonnages of the concentrate to metallic iron in relatively small units, an improvement might be made in the production of iron.

Many attempts have been made to develop methods for the direct reduction of iron oxides to metallic iron. These methods have employed various types of reducing equipment, including rotary kilns, hearth furnaces, sintering machines, and fluidized beds. Crude ore amenable to concentration at a coarse particle size or pelletized concentrates can be treated in kilns, shafts, or retorts. However, of the available types of equipment the fluidized-bed units have shown the greatest promise for the direct production of iron from finely-divided material, such as the concentrates currently being produced from low-grade iron ores. The fluidized bed's main advantages are the excellent gas-solid contact and temperature control.

With normal fluidized-bed reactors, however, several disadvantages also exist. The volume of gas that can be passed through the reactor is a function of the gas velocity that can be used without entraining the finely-divided solids and, in turn, the amount of material that can be treated is dependent on how much reducing gas can be passed through the reactor. Because of these limitations imposed by the gas phase, it is interesting to examine the role of the gas phase in the reduction of iron oxides to metallic iron.

Fundamental considerations

An examination of the chemical equilibrium data for the systems Fe-H_2-O_2 and Fe-C-O_2 shows some interesting relationships. Fig. 1 gives the basic equilibrium curves for these systems and shows that, in reducing Fe_2O_3 or Fe_3O_4 to metallic iron with either CO or H_2, less than half the reducing gas can react without encountering a reversal of the reaction. This means that to obtain complete reduction of iron oxides to metallic iron gas flows considerably in excess of stoichiometric requirements are needed.

Another consideration is the rate at which ferric oxides can be reduced to either magnetite or to metallic iron. Several excellent studies have been made on the kinetics of iron-ore reduction[1, 2, 3] and, while there is some difference of opinion as to the controlling mechanisms, all of the investigators are in agreement that, within a given set of conditions, the rate of reduction is inversely proportional to the size of the particle being reduced. Thus, the finer the particle size, the more rapid the reduction rate; however, the finer the particle size, the lower the gas velocity that can be tolerated in a fluidized-bed unit. So in normal fluidized-bed units a compromise must be made between rapid reaction rates and the ability to use large volumes of reducing gas to obtain high capacities.

Operation of the unit under pressure offers some promise of increasing gas volume but this, of necessity, increases the capital cost of the equipment.

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While equilibrium considerations indicate that ferric oxides can be reduced to metallic iron at relatively low temperatures, kinetic considerations indicate that elevated temperatures are required to obtain reductions in reasonable lengths of time. On this basis, it would appear that, because higher capacities could be obtained with higher temperatures, it would be desirable to operate reactors at the highest possible temperatures. However, there are other aspects of operating at elevated temperatures that must be considered.

Probably the most important factor connected with high-temperature operation is the physical condition of the material in the fluidized bed. At temperatures above 1400°F, metallic iron becomes plastic and the fine particles tend to agglomerate, thus defluidizing the bed. Two alternatives are available to improve the physical conditions of the bed: to operate at lower temperatures; or to control the reduction to avoid complete reduction. Both alternatives have disadvantages. If lower temperatures are used, a pyrophoric product is produced which must be processed further by compacting or heat treating. If incomplete reduction is used, the end product has a more limited use than if it was reduced completely to metallic iron. In either case, however, it is necessary to maintain close temperature control not only of the average charge, but of individual particles as well.

Having discussed some of the fundamentals of fluidized-bed operation in relation to iron-ore reduction, it is interesting to compare these fundamentals and to pick the preferred conditions for operation:

Feed Size

As coarse as possible to allow maximum gas flows, but

As fine as possible to allow maximum reaction rates.

Temperatures

Above 1400°F to give maximum reaction rates and to produce a nonpyrophoric product, but

Below 1400°F to avoid sticking and defluidization of the bed.

Gas Velocities

As high as possible to give the maximum amount of reductant and high heat transfer rates, but

As low as possible to avoid entrainment and dust carryover.

In considering these conditions, it becomes obvious that the ideal system would be one that could operate at elevated temperatures with finely-divided feed at a high unit capacity in unpressurized equipment, while producing an agglomerated end product which is nonpyrophoric. This paper describes the development of such a process and presents some of the data obtained from a research program which has been carried out to demonstrate the basic concepts of the process.

The proposed process is carried out in a modified fluid bed in which the fine feed is self agglomerating. This permits the use of high gas velocities and results in high unit capacities at low pressures. The known phenomenon that freshly reduced metallic iron softens and becomes sticky at high temperatures is used to agglomerate the fine feed and produce an agglomerated, nonpyrophoric end product. At the same time, because the reduction of finely-divided iron oxide occurs only at the surface of the agglomerates, fast reaction rates can be maintained.

Self agglomeration

In any fluidized-bed system the particles being fluidized are constantly in motion and undergo a continuing series of contacts with each other. For this reason, it is normally difficult or impossible to fluidize any material which becomes sticky or soft while being treated, because the particles tend to stick together and form a single large piece which cannot be fluidized.

The tendency for particles to stick together when they collide depends on three factors:

A) their adhesive properties;

B) the area of contact; and

C) their momentum. The tendency to stick is directly proportional to the adhesive force and area of contact and inversely proportional to their momentum. Thus, stickiness, $S = f\left(\frac{A \times B}{C}\right)$.

In a system containing only small particles which are soft or semi-molten, the adhesive force and area of contact are relatively large, while the momentum is small because of the large surface area to mass ratio of the particles. Thus, the entire bed tends to fuse or stick into a single mass. On the other hand, it is possible to control this stickiness or fusion by controlling the adhesive properties and by increasing the size of the particles being fluidized.

In the system where iron oxides are being converted to metallic iron, only the metallic iron is plastic or sticky. The degree of plasticity and, therefore, the adhesive force is dependent on the tem-

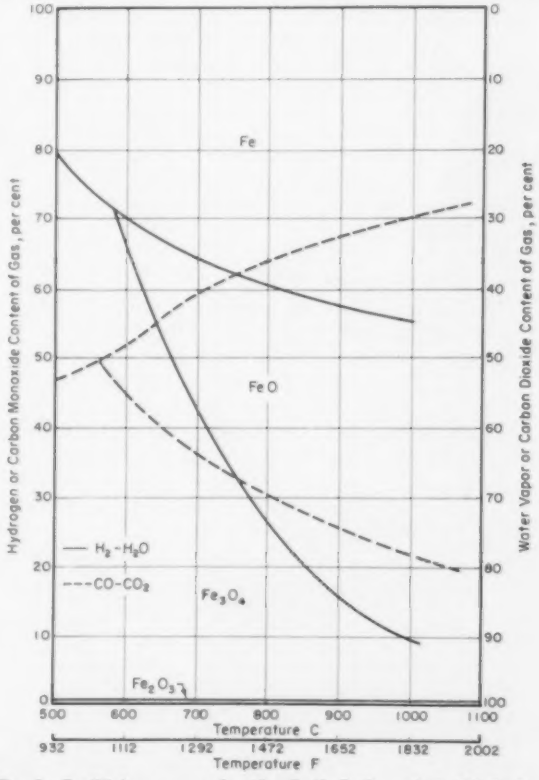

Fig. 1—Equilibrium curves for the Fe-H_2-Fe_2O_3 and Fe-CO-Fe_2O_3 systems.

perature. Increasing the temperature increases the plasticity or adhesive characteristics, so that in this system the degree of stickiness can be controlled by controlling the temperature. Likewise, the momentum and relative area of contact can be controlled by controlling the gas velocity and particle size of the material being fluidized. Since in a normal fluidized-bed reactor the material being fluidized is practically the same as the finished material, this means controlling only the size of the reduced iron particles.

Thus, it would be possible to fluidize metallic iron pellets of say ⅛-in. diam at temperatures higher than could be used for — 100-mesh particles. At the same time, although the larger particles would not stick together because of their limited area of contact and high momentum, they would still exhibit a relatively sticky or adhesive surface which could capture fine particles that were being passed through the bed. Thus, it becomes possible to feed finely-divided iron-oxide particles to a bed of pelletized iron particles and have the fine oxide adhere to the surface of the larger pellet, thereby causing it to grow in size through self agglomeration of the fine feed.

During this growth cycle, it is believed that several other phenomena also aid the proposed system. First, only a limited layer of iron oxide can be collected on the surface of the reduced pellet without causing the surface to be completely covered with a nonplastic iron oxide coating which can no longer capture fresh feed particles until the iron-oxide layer is reduced to metallic iron. Thus, the actual reduction reaction takes place only at the surface of the pellet and does not require diffusion of the hydrogen into the center of the pellet nor diffusion of water vapor out from the center of the pellet. This surface reduction is, therefore, much more rapid than a similar reaction would be if pellets made up completely of iron oxide were being reduced.

Secondly, once the pellets have grown to a sufficient size so that they become less easily fluidized they tend to segregate to the bottom of the bed where they can be withdrawn as a finished product of controlled size.

Table I. Comparison of the Distribution of Particle Size and Surface Area of a Nonfluidizable Charge with a Fluidizable Charge

	Bed A, Nonfluidizable		Bed B, Fluidizable	
Size, Mesh US Std	Wt Pct	Dist Surface Area, Pct	Wt Pct	Dist Surface Area, Pct
−20 + 30			18.2	9.9
−30 + 40	3.9	2.6	45.1	34.6
−40 + 50	30.4	26.4	19.3	20.1
−50 + 60	56.5	59.0	6.9	9.2
−60	9.2	12.0	10.5	26.2

Table II. Comparison of the Particle Size Distribution of a Starter Bed With the Final Product

Starter Bed			Final Bed		
				Wt Pct	
Particle Size, mm	Wt Pct	Surface Area, Pct	Particle Size, mm	Actual	Calc
−0.84 + 0.59	55.6	43.7	+ 0.82	51.4	51.0
−0.59 + 0.42	30.0	33.8	−0.82 + 0.61	21.8	23.0
−0.42 + 0.30	14.4	22.5	−0.61 + 0.46	16.8	16.0

Finally, there is evidence to support the belief that during the course of the reaction a minor number of finely-divided feed particles are reduced to metallic iron in the gas stream without being attached to the larger pellets. Furthermore, these particles, because of their large surface area to mass ratio, tend to bond to other small feed particles and thus form nuclei for perpetuating the grain growth or self-agglomeration condition.

In summation, then, the self-agglomeration phenomenon is caused by the fact that in a fluidized bed large particles or pellets having a relatively sticky surface (such as is exhibited by freshly reduced metallic iron at temperatures above 1400°F) can be fluidized without sticking to each other, but small particles of fresh iron-oxide feed will stick to the large particles, causing them to grow in size. Because the reduction of iron oxide takes place at the surface, the reaction is rapid, and the finished particles have an *onion-skin* growth pattern. The phenomenon is self perpetuating because fresh nuclei are formed autogenously in the bed.

Effect of particle size

The amount of gas that can be passed through a fluidized-bed reactor, or more properly the permissible gas velocity, is largely controlled by the size of the particles being fluidized. If the velocity exceeds the entrainment velocity as predicted by Stokes' law,* then the particles in the bed will not remain fluidized, but will be entrained and carried out with the gas.

Stokes' law shows that doubling the particle size permits the use of four times as high a gas velocity as could be tolerated for the smaller particle. Or in the case of the fine iron-ore concentrates (which are essentially — 100-mesh or less than 0.015 cm in diam) only 1/400 of the gas velocity used with ⅛-in. pellets (0.32 cm) could be used for fluidization.

Because the amount of iron oxide that can be reduced to metal is primarily dependent on the amount of reducing gas that can be passed through the unit, it is theoretically possible to reduce 400 times as much iron oxide in a given unit when treating ⅛-in. pellets as could be reduced when treating — 100-mesh particles. To obtain the same result by increasing the gas pressure would require the unit to operate under a pressure of 400 atm or 6000 psia.

In summation, the ability of the proposed system to take finely-divided feed and treat it as though it were ⅛-in. pellets allows a given unit to process feed at a capacity up to 400 times as great as would be anticipated if — 100-mesh particles were being processed.

Effect of temperature

Fine iron-oxide concentrates which are completely reduced to metallic iron at temperatures below the softening point of iron exhibit a tendency, even after careful cooling, to be pyrophoric and to reoxidize with a violent and almost instan-

* Stoke's law, $V = \frac{2g\,r^2(d_s - d_f)}{q\,n}$

where, g = gravitational constant, r = radius of particle, d_s = density of particle, d_f = density of fluidizing medium, and η = viscosity of fluidizing medium.

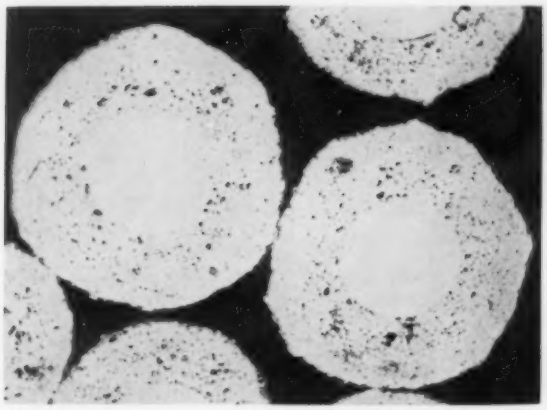

Fig. 2—Typical particles from the self-agglomerating fluidized bed. Operating temperature: 1500°F. X50, reduced to 87 pct for reproduction.

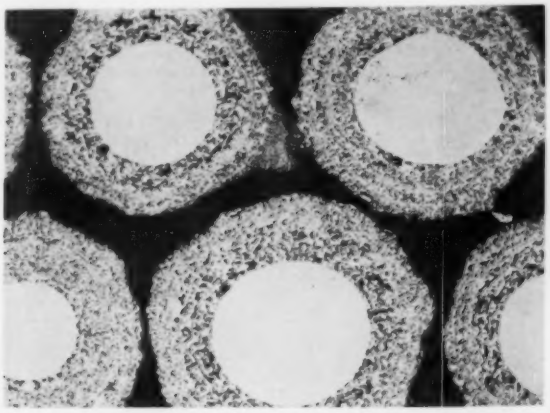

Fig. 3—Typical particles from the self-agglomerating fluidized bed. Operating temperature: 1600°F. X50, reduced to 87 pct for reproduction.

taneous reaction on exposure to air. On the other hand, iron oxide reduced above its softening point is quite inert when cooled and exposed to air. Thus, the self-agglomerating process operating at an elevated temperature produces a product that is easily handled and stored, even though it is completely reduced to a metallic state. This simplifies handling the material and eliminates the need for briquetting or compacting the product in an inert atmosphere. However, if compaction is required, for example to improve an electric furnace operation, it would be simple and inexpensive on nonpyrophoric material.

Experimental work

Particle Size Distribution

During the development of the process, many experiments were run on several different types of feed material under a variety of conditions. In this paper, typical data are presented to verify the basic concepts of the process as already described.

The outstanding feature of the process is the mechanism which gives adhesive properties to the particles and, at the same time, permits fluidization of the bed. This mechanism can be demonstrated by analyzing the data obtained from experiments using a starter bed of a predetermined particle size consist and an iron-oxide concentrate which was over 90 pct −325 mesh as feed to the fluidized-bed reactor.

Table I gives the screen analyses and the calculated percentage of surface areas in each size fraction in the two starter beds used. When the −325-mesh iron concentrates were fed to bed A, fluidization could not be maintained at a temperature of 1400°F, and only a small amount of the feed was agglomerated to the particles in the fluidized bed.

The nonfluidizable starter bed contained approx 96 pct of the weight and 97 pct of the surface area in the −40-mesh fractions. By comparison, in the fluidizable mixture only about 37 pct of the weight and 55 pct of the surface area were in the −40-mesh fractions. Although −40-mesh has been used as the size fraction for purposes of discussing these particular starter beds, the important factor is the relation between the mass and adhesive force of the coarser particles and that of the smaller fractions.

The fact that the coarser starter bed could be fluidized at temperatures as high as 1600°F, whereas the other bed defluidized at 1400°F, is in accordance with the concept that the tendency to stick is directly proportional to the adhesive force and area of contact, and inversely proportional to the momentum. In other words, in the coarse starter bed the particles had a greater mass and thus greater momentum. Thus, in the relation,

$$\text{Stickiness} \propto \frac{\text{adhesive force} \times \text{area of contact}}{\text{momentum}}$$

the tendency of the larger individual particles to stick together would be less than that of those in the finer size bed where most of the individual particles have a small mass. Therefore, a greater adhesive force (or higher temperature) could be tolerated without causing defluidization of the coarser particles.

Particle Growth

Another interesting theory is the relationship between surface area of the particles in the bed and the agglomeration of the iron ore concentrates fed to the fluidized-bed reactor. If the concepts pertaining to the factors which cause stickiness of the bed are valid, the fresh feed should be agglomerated to the bed particles in direct proportion to their surface area. To demonstrate the validity of this concept, the weight gained by the fluidized-bed charge during an experiment at 1550°F was distributed to each size fraction in the starter bed in proportion to the surface area of the particles in each size fraction, and a screen analysis was calculated for the product. Table II compares the particle size distribution of the synthetic starter bed with the calculated and actual distribution of particle sizes obtained experimentally.

The close correlation between the actual and calculated weight percentages of the final bed for these and other similar experimental data tend to confirm the validity of the premise that growth of particles takes place as a function of their surface area.

Physical Structure of Particles

The fact that the bed particles grow in relation to their surface area supports the theory that reduction of the iron oxide takes place at the surface of the coarser pellets. This theory is further substantiated by photomicrographs of the products. Fig. 2 shows normal pellets taken from the final bed of an experiment carried out at 1500°F. The dense white

core represents the residual cast shot used as a starter bed, while the onionskin outer layers represent the growth caused by reduction *in situ* of the fine iron oxide. Likewise, Fig. 3 shows the same general pattern but with a denser outer layer or growth ring. This sample was taken from a bed operating at 1600°F and shows the denser structure which is obtained from operation at higher temperatures.

Self Nucleation

In addition to the need for demonstrated particle growth, the proposed system must be self nucleating if it is to remain a stable system. To do this, it is necessary that new fine-sized particles be produced by the system to serve as nucleating centers for additional growth. The system has this property, as can be shown from examination of the data in Table III. These data were obtained from a series of experiments in which the unit was periodically shut down, the bed discharged, the oversize and undersize material removed, and the balance of the bed material recycled.

Examination of these data reveals that in each cycle, 30 to 45 pct of the final bed was removed as oversize or + 20-mesh material, and that of the remaining material, 12 to 25 pct was present in the − 40-mesh fraction. This − 40-mesh fraction represents new nucleation surfaces which have been formed in the system. The probable mechanism for their formation is the reduction of fine iron oxide to metal prior to its agglomeration to larger particles. The reduced particles, in turn, probably join together to form new nucleating centers composed of several small feed particles grouped together.

Proof of this theory rests in particles taken from the third cycle bed. These particles did not contain cast shot centers (original starter bed) but were composed entirely of reduced iron oxide; they were spherical in shape and still exhibited the normal onionskin growth pattern for the outer layers.

Feed Capture

The system's ability to capture and retain feed has been shown to be dependent on the adhesive force and on the surface area. In addition, because capture is a function of probability, bed depth is also a factor.

To be captured, a feed particle must first contact a pellet surface. The probability of this occurring is a function of gas velocity and bed depth. Secondly, the surface contacted must be one which will accept the feed particle. This means that it must be a metallic iron surface and must be at a temperature sufficiently high to have the adhesive force necessary to hold the particle.

To date no exact data are available to set limits or predict design data for determining optimum reactor size to give maximum feed capture. However, some interesting data are available which give an indication that these factors lie within reasonable limits. For example, capture rates of over 75 pct have been achieved in beds 6-in. deep operating at 1550° to 1600°F, and capture rates of over 95 pct have been obtained in beds 3 ft deep at 1500°F.

General Considerations

In the small-scale work used to demonstrate the self-agglomeration process, the objective was to produce material in the size range −12 +20-mesh by direct reduction of − 325-mesh iron concentrates. To maintain fluidization of the bed at 1550°F and to agglomerate the iron concentrates to this size required a superficial gas velocity of 10 fps.

The process has been demonstrated under conditions which resulted in the production of − 6-mesh + 8-mesh pellets of reduced iron concentrates. A superficial gas velocity of 35 fps was required for fluidization of the self-agglomerating bed.

It is believed that the economics of pumping and recycling the reductant is the limiting factor as to the maximum particle size that can be produced by the self-agglomerating fluidized-bed reactor. With the proper starter bed and space velocity, it is believed that ¼-in. pellets might be produced by this process.

Finally, in every experiment at temperatures in the range 1400° to 1600°F, the agglomerated product from the fluidized-bed reactor was nonpyrophoric and assayed over 98 pct metallic Fe.

Conclusions

It is believed that the data obtained from the experimental work on the direct reduction of finely-ground iron concentrates with hydrogen has demonstrated a mechanism which utilizes the adhesive characteristics of the particles in a fluidized bed for the production of agglomerated particles of a controlled size.

Although this paper has considered only the self agglomeration of iron concentrates to produce metallic iron, it is expected that the basic concepts of the process would be applicable to other materials which have, or could be made to have, adhesive properties at the operating temperature of the fluidized-bed reactor.

References

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[2] B. Stalhane and T. Malmberg: *Jernkontorets Annaler*, vol. 114, pp. 1-26, 1930.
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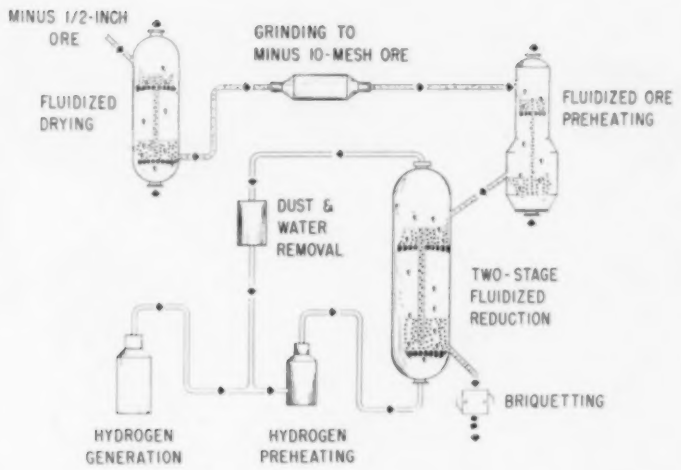
Table III. Experimental Data from Self Nucleation Tests

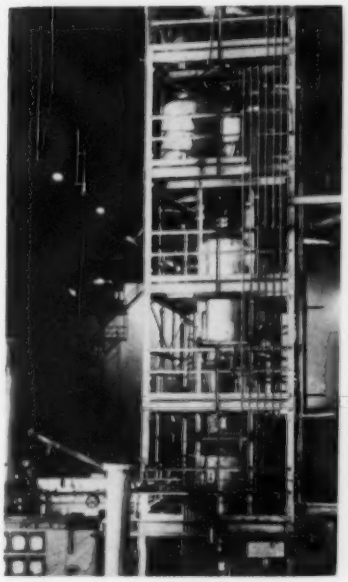
Size, Mesh US Std	Wt Pct First Cycle			Wt Pct Second Cycle			Wt Pct Third Cycle		
	Starter Bed	Final Bed	Final Bed Less Oversize	Starter Bed[a]	Final Bed	Final Bed Less Oversize	Starter Bed[b]	Final Bed	Final Bed Less Oversize
+ 20		32.1			42.3			44.6	
− 20 + 30	18.2	33.6	49.4	55.6	38.1	66.0	67.0	36.2	65.4
− 30 + 40	45.1	18.3	27.0	30.0	12.5	21.7	22.0	10.1	18.2
− 40	36.7	16.0	23.6	14.4	7.1	12.3	11.0	9.1	16.4

[a] − 20-mesh + 50-mesh material from final bed of first cycle.
[b] − 20-mesh + 50-mesh material from final bed of second cycle.

NU-IRON,

A Fluidized-Bed Reduction Process





In pilot-plant tests, U.S. Steel Corp. has shown that its two-stage iron-ore reduction process utilizing hydrogen is technically feasible. A 2000-tpd commercial unit has been designed, but economic considerations have delayed construction.

by T. F. Reed, J. C. Agarwal, and E. H. Shipley

A substantial portion of the iron-bearing material now available to the iron and steel industry for charging to blast furnaces is of a size-consist such that optimum furnace performance can be obtained only if the iron-bearing material is first agglomerated. This fact may be true to an even greater degree with respect to the iron-bearing materials that will be available to industry in the future. This situation, added to the fact that some of this iron-bearing material is of a relatively high purity, has suggested the possibility of bypassing both the agglomerating process and the blast furnace, and instead, reducing the unagglomerated iron-bearing material at a single step, using fluidized-bed techniques to produce a material suitable for steelmaking. The tempting possibility of thereby being able to expand steelmaking into areas where metallurgical coke is unavailable or very expensive provided the necessary incentive for investigating fluidized-bed reduction processes. Recognizing these possibilities, U. S. Steel Corp. has been active for the past six years in developing the Nu-Iron fluidized-bed reduction process.

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Thermodynamic considerations

As is well known, the rate of reduction of iron oxide increases rather rapidly with temperature (Fig. 1). On the other hand, at certain temperatures the reduced iron-powder particles have a tendency to stick not only to the walls of the reactor but also to each other; this tends to cause defluidization of the bed. Finally, iron reduced at a temperature below 1100°F is pyrophoric; therefore, special procedures are required to handle the product safely.

After reviewing these basic factors, it was decided to investigate the reduction of iron oxide in the temperature range of 1200° to 1400°F where: 1) the reaction rates are fast, 2) defluidization tendencies are

not severe and can be overcome, and 3) the powder produced is not pyrophoric when cold.

Further consideration was then given to thermodynamic equilibrium, which dictates that below approx 1100°F, FeO cannot exist and that the reduction path is from Fe_2O_3 to Fe. If the reduction is performed below 1000°F by the route Fe_2O_3 to Fe, the equilibrium constant for the reduction with hydrogen is very low; hence, only a very small quantity of the hydrogen reacts with Fe_3O_4 to give iron. For example, with hydrogen as the reducing gas at 900°F only 14.5 pct of hydrogen can react. If a mixture of H_2 is utilized, the reduction is hindered because the CO and H_2 react together to give methane.

When the reduction is performed at 1300°F, Fe_3O_4 cannot reduce directly to iron, but must reduce first to FeO; then FeO reduces to Fe. The equilibrium constant (Fig. 2) of 1.2 for the reduction of Fe_3O_4 to FeO with hydrogen is considerably higher than that of 0.42 for the reduction of FeO to Fe. Accordingly, the off-gases from the reduction of FeO to Fe will have reducing power left over for the reduction of Fe_3O_4 to FeO. This is fortunate, because it opens up the possibility of a two-stage reduction process in which Fe_3O_4 will be reduced to FeO in the first stage with the off-gases from the second stage, and the FeO will then be reduced with fresh reducing gases to Fe in the second stage. Utilization of the off-gases from the FeO to Fe reduction to reduce Fe_2O_3 or Fe_3O_4 to FeO results in a marked improvement in the proportion of the reducing gases utilized in the reduction process. Furthermore, a two-stage process will have less bypassing of the solids and the gases.

In addition to these thermodynamic considerations, economic analysis indicated that recycle of partially-spent reducing gas would be essential. Under these conditions, any carbon-bearing gas would ultimately be removed from the system as carbon dioxide. If a mixture of carbon monoxide and hydrogen was used as the reductant, the carbon dioxide would have to be removed from a relatively large stream of recycle gas. Further economic analysis indicated it would undoubtedly be cheaper to convert the carbon monoxide in the fresh reducing gas to carbon dioxide by water-gas shift and remove the carbon dioxide from a relatively small volume of fresh reducing gas.

The process

With these fundamental concepts in mind, the Nu-Iron process was conceived. In essence, the process consists of the following steps:

Dried ore sized to −10 mesh is preheated to approx 1600°F in a separate multi-stage ore heater. This is approximately 300°F higher than the reduction reaction temperature, in order to supply the required endothermic heat for the reduction of Fe_2O_3 or Fe_3O_4 to FeO.

The preheated ore is transferred continuously to the first stage of the reducing reactor, where it is reduced to FeO at 1300°F and 15 to 25 psig by the hot off-gases from the second stage. The partially-reduced ore flows continuously to the second stage of the reducing reactor, where it is reduced to powdered iron at 1300°F by the fresh reducing gas. The 90 to 95-pct reduced iron powder is briquetted, cooled, and stored for processing into steel. No passivation of the briquettes is required, because the cold briquettes are not pyrophoric and do not oxidize on exposure to weather.

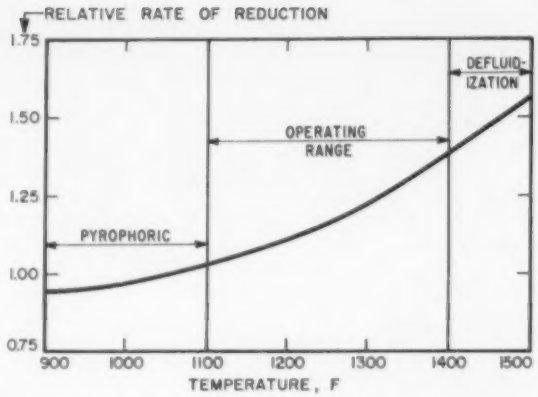


Fig. 1—Effect of temperature upon rate of reduction in Nu-Iron process.

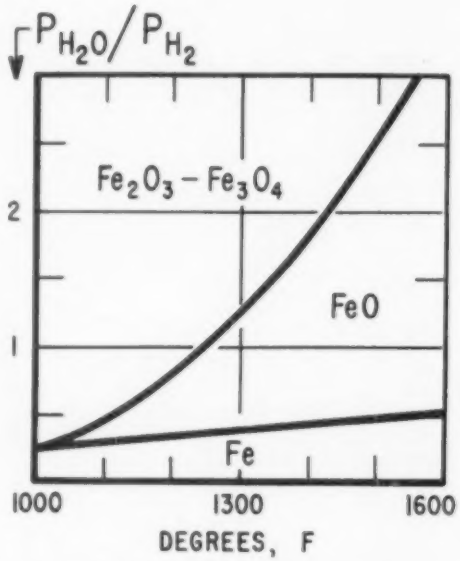


Fig. 2—Equilibrium constants for iron oxide reduction.

The make-up reducing gas, which in most of our pilot-plant development work was 97 to 98 pct pure H_2, is mixed with the purified recycle gas and heated to approximately 1600°F. The preheated reducing gas at 50 psig and 1600°F is introduced at the bottom of the second stage of the reducer, where it supplies the endothermic heat of reaction and completes the reduction of the FeO from the first stage to iron powder. The off-gases from the second stage continue to the first stage of the fluidized reactor, where they partially reduce Fe_2O_3 or Fe_3O_4 to FeO. The hot dust-laden gases at 1300°F are partially cooled by exchanging heat with the cold reducing gases. The partially-cooled gases are cleaned and further cooled in a cold-water scrubbing tower, where the water formed in the reduction of iron oxides by hydrogen is removed prior to compression and recycle.

In the Nu-Iron process, because the reduction is performed under the conditions of the Fe_2O_3-to-FeO

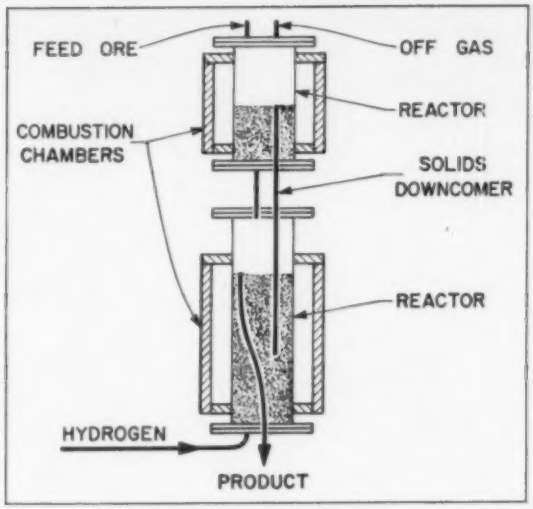


Fig. 3—Pilot-plant reactor construction.

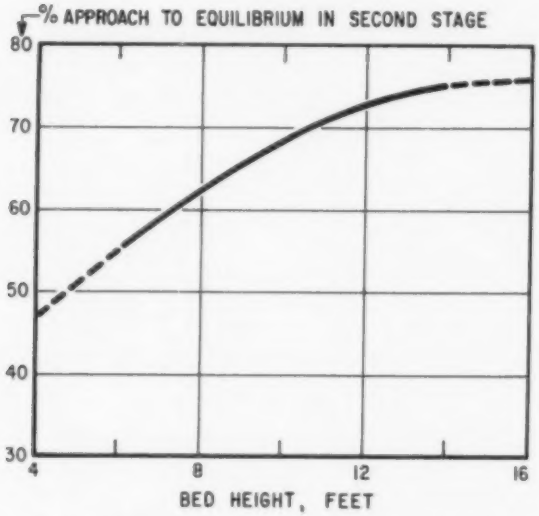


Fig. 4—Effect of bed height on the approach to equilibrium.

and the FeO-to-Fe equilibria, 32 to 36 pct of the H_2 in the reducing gas is converted to water in the reduction of the iron oxide. From thermodynamic equilibrium considerations, this is a highly efficient use of the reducing gas in a single pass through the reactor. As a result, in the Nu-Iron process the ratio of recycled gas to the fresh make-up is only 2:1. Accordingly, the cost of purification and recompression of the recycle gas is considerably lower than that obtained in processes in which the reducing gas is utilized under less favorable equilibrium relationships.

To prevent the inerts in the fresh make-up gas from building up to an excessively high fraction of the total reducing-gas stream, a small amount of purified gas is purged, and the concentration of the inerts (carbon monoxide and carbon dioxide) in the reducing gas going to the reactor is controlled at approx 15 pct. Here again, because of the high efficiency of utilization of the reducing gas in the Nu-Iron process, the amount of reducing gas thus purged or wasted from the reduction system is only about 5 to 7 pct of the fresh make-up gas when the make-up H_2 is 98.5 pct pure.

The fresh make-up gas can be produced from any source of hydrocarbon—such as fuel oil, natural gas, coke-oven gas, or coal—by any of the several available processes, such as partial oxidation or catalytic steam reforming. In the commercial design of the Nu-Iron process, 98.5 to 99.9 per cent pure H_2 could be utilized as the make-up gas.

Pilot Plant

To obtain design and development information on the Nu-Iron process, U. S. Steel Corp. built and operated a pilot plant at the ore-treating laboratory of the South works in Chicago.

In the pilot-plant, make-up gas is produced in a tube-type reforming furnace by reacting natural gas (desulfurized with activated charcoal) with steam in the presence of a catalyst at 1600° to 1800°F. The hot, reformed gas contains H_2, CO, CO_2, and H_2O. The CO in the reformed gas is converted to CO_2 in a water-gas-reaction shift converter by reacting the CO with steam in the presence of a catalyst at 600° to 800°F. The gas leaving the shift converter is cooled to condense water vapor.

After compression to 60 psig, the cooled gas is scrubbed with aqueous mono-ethanolamine in a packed adsorption column to remove CO_2. The gas leaving the CO_2-removal unit contains approximately 97 pct H_2. The mono-ethanolamine solution is reactivated by heating with steam in the stripper.

This fresh make-up gas is mixed with cooled, cleaned, and compressed recycle gas from the reduction system. The mixture, called *reducing gas*, goes to the ore-reduction system.

Reducing gas is first preheated to reaction temperature in an indirectly-fired tubular heater and then sent to the bottom reactor. The gas passes upward through the two reactors, fluidizing and reacting with the solids in each bed. To minimize dust carry-over between stages, the gas from the bottom bed passes through an external cyclone before entering the top bed. The dust from this cyclone is collected, weighed, and analyzed. After the off-gas leaves the top reactor, it is cleaned by being passed through a series of cyclones, a venturi scrubber, and an entrainment separator. The dust collected in the cyclones is returned to the top bed. The cleaned gas is cooled in a direct-contact water cooler, which also serves to condense the water formed in the reaction between hydrogen and iron oxide in the beds. Part of the cooled-gas stream is purged to remove inerts from the system; the remainder is recycled to be mixed with fresh make-up gas.

The fluidized-bed ore-reduction unit (shown in Fig. 3) consists of two 16½-in. ID stainless-steel vessels mounted one above the other to allow for continuous gravity flow of solids downward and a countercurrent flow of gas upward. Each vessel is surrounded by a furnace chamber in which natural gas is burned to maintain the fluidized bed at the desired temperature. In the top vessel (first stage), the incoming ore feed is reduced to FeO (equivalent to 33 pct reduction) by the off-gas from the lower vessel. The solid product from the primary reactor is then, in turn, reduced to metallic iron in the lower unit (second stage) by the incoming reducing gas.

Considerable design information was obtained from the operation of this pilot plant. In a typical run, the temperatures at the top first-stage and second-stage fluidized beds were controlled at 1300°F. The bed height of the first stage was maintained at 5.5 ft and that of the second stage at 12 ft by means of properly sized downcomers. The reducing gas was 85 pct H_2 at a flow rate of 6250 std cu ft per hr. This gas flow maintained a fluidization velocity of 1.5 ft per sec in the second stage. The fresh make-up gas was 97 pct H_2 at a flow rate of 1829 std cu ft per hr. Dried −10-mesh Venezuelan ore was fed to the Nu-Iron pilot plant at the rate of 250 lb per hr. The over-all rate of oxygen removal in the pilot plant was 64 lb per hr. Approximately 90-pct reduced iron was withdrawn from the system at 184 lb per hr. The reduced iron powder was briquetted in a roll-type press for use in steelmaking.

As indicated earlier, the controlling equilibrium in the reduction of iron oxide is the equilibrium of FeO to Fe, and in the Nu-Iron process this reduction occurs in the second stage. The extent to which this equilibrium is approached in the second stage of reduction is a measure of the efficiency of the process, and it governs the production capacity of a given unit. As can be seen in Fig. 4, the approach to equilibrium increases with increasing bed height of the second stage, up to a bed height of 12 ft. In the Nu-Iron pilot plant, we have consistently obtained 70 pct or better approach to equilibrium of the gas for the FeO to Fe reduction in the second stage with a 12-ft bed height. In fluidized beds, because some bypassing of the gas necessarily occurs, efficiencies of a 70 to 80 pct approach to equilibrium are all that can be expected. In the hope of decreasing the bypassing of the reducing gas, the height of the second-stage fluidized bed was increased above 12 ft, but this did not have any appreciable effect on the approach to equilibrium.

There has been some concern over sticking or defluidization of an iron-reduction fluidized bed. In the Nu-Iron pilot plant, we were able to operate without defluidization or sticking in the beds as long as the process conditions were controlled properly. The range in which defluidization does not occur at these high temperatures for highly reduced product is very narrow. Precise process control is necessary. U. S. Steel is investigating this phase of fluidized reduction more thoroughly, and we will report on it in the near future.

Commercial plant designed

With the encouraging results and the information obtained in the pilot plant, we undertook to design a 2000-tpd Nu-Iron plant. This commercial plant includes the following major functions:

Minus ½-in. ore is first dried in a fluidized-bed drier, and the + 10-mesh material from this drier is ground in a closed-circuit rod mill grinding system to produce a −10-mesh feed for the Nu-Iron process. The dried −10-mesh ore is conveyed to a two-compartment fluidized-ore heater in which the ore is heated to approximately 1600°F.

The preheated ore is transferred to the ore reducer, in which the ore is reduced first to FeO and then to approximately 90 pct reduced iron powder. This product is transferred to a stripper that strips out entrained hydrogen and is then briquetted while hot. The briquettes are cooled in an inert atmosphere to produce material for the steelmaking operation.

The hydrogen is produced from natural gas or fuel oil, for example, by the partial-oxidation process in which the fuel reacts with oxygen to produce synthesis gas. Most of the carbon monoxide in the synthesis gas is then converted to carbon dioxide by the water-gas-shift reaction in a primary shift converter. The carbon dioxide so produced is absorbed in a hot potassium carbonate scrubber. The remaining carbon monoxide is converted to carbon dioxide in a second shift converter, and the carbon dioxide so generated is absorbed in an M.E.A. scrubber. The purified high-pressure gas stream, now 98.5 pct H_2, is sent to a recycle system.

In the recycle system off-gases from the reducer give up heat first to the incoming fresh hydrogen, next to the reducing gas going to the reducing gas heater, and finally to the cooled and recompressed recycled hydrogen. The partially-cooled off-gases are next cleaned and cooled to room temperature in a water scrubber. The cooled gas is then recompressed to 50 psig and reheated by heat exchange with the hot off-gas in a heat exchanger; it combines with the fresh hydrogen before being heated further in a second heat exchanger. The combined gas stream, now called the reducing gas, is heated to the desired temperature of 1600°F in a direct-fired reducing-gas heater and passed to the reducer.

Part of the power required for the compression of the recycled gas is obtained by expanding the preheated, high-pressure, fresh hydrogen in a turboexpander. After expansion, the make-up hydrogen joins the recompressed recycle gas.

Economic realities

In view of the facts that the Nu-Iron pilot-plant results look good and that a commercial-size plant has been designed, it is natural to wonder why a commercial plant has not yet been built. The reason is not one of technical difficulty, but rather one of economics. Careful evaluations have indicated that in its present stage of development and under prevailing conditions, the Nu-Iron process is not competitive with the blast-furnace process as a source of iron units for producing steel ingots in the continental US, except in a few areas where coking coals are not available and natural gas is very cheap. It should be remembered that the cost comparison, to be valid, must be based on the cost of making steel ingots from two different sources of iron units: molten metal and cold briquettes. Thus, the Nu-Iron product has the economic disadvantage that it requires additional heat for melting in the steelmaking process.

However, our analysis has indicated that the Nu-Iron process would be competitive in special situations. One of these obviously would be that in which the cost of the hydrogen required per ton of Nu-Iron was cheap in comparison with the cost of the coke required per ton of hot metal. Considerable work is now underway throughout the world on processes for making cheap hydrogen, and a breakthrough in this area would have a great impact on fluidized-bed reduction processes. Another special situation might be one in which the iron ore was so contaminated with deleterious substances as to make its use in a conventional blast furnace impractical. Here, the Nu-Iron process would provide a means of exploiting iron-ore reserves that might otherwise be unusable.

Based on these facts, U. S. Steel Corp. has decided to continue the development of the Nu-Iron process with special emphasis on the economics.

H-IRON PRODUCTION

By Alan Wood

In April 1957, JOURNAL OF METALS published an account of the H-Iron pilot plant at Trenton, N.J. Here is the story of the first commercial H-Iron installation, the Alan Wood Steel plant for the production of iron powder. A second commercial unit is now under construction by Bethlehem Steel in southern California.

by Robert A. Lubker and Kenneth W. Bruland

THE first commercial H-Iron plant for the production of iron powder is now being operated by the Alan Wood Steel Co. at Conshohocken, Pa. With a rated capacity of 50 tpd or 18,000 tons per year, Alan Wood is the second largest producer of iron powder in the Country.

Historically, the interest of Alan Wood in iron powder stemmed from the availability of a raw material uniquely suited for the manufacture of this product. Since 1929, the firm has operated the Scrub Oaks mine in Dover, N.J. This is the largest known magnetite deposit in that state, with mine output on the order of 3500 tpd. The ore averages 28 pct Fe; it is crushed to ⅛-in. lumps and the magnetite removed from the gangue by magnetic separators. This concentrate analyzes about 67 pct Fe and goes to blast furnaces at Conshohocken, Pa. More recently, the company has been interested in the development of magnetite grades suitable for other applications. The regular grade concentrate was found to contain a large portion of −30 mesh particles which were nearly free of impurities. Removal of these particles by additional grinding and gravity separation resulted in a product containing over 71 pct Fe which is marketed as *high-grade concentrate* and has been accepted for application in many chemical processes.

With this unusually pure source of iron, the company realized that it had an excellent starting material for the production of high-quality iron powder and undertook a diligent research program toward that goal. Many methods of reducing iron oxide by carbon and hydrogen were studied. After careful consideration of all possible processes, including a high temperature reduction process developed and piloted in our own laboratories, the H-Iron process was selected. This process, which was developed by Hydrocarbon Research Inc. in cooperation with Bethlehem Steel Co., uses a fluid bed to reduce iron-oxide particles to iron powder. The shortcomings of previous attempts to utilize such methods were overcome in work done by Hydrocarbon Research in the petroleum field and demonstrated by a plant at Brownsville, Tex., which was successfully operated for three years—producing about 20 tons of iron powder per day. This powder was used as a catalyst in a synthetic gasoline plant.

ROBERT A. LUBKER and KENNETH W. BRULAND are with the Alan Wood Steel Co., Conshohocken, Pa. This paper is being presented at the 1960 AIME Blast Furnace, Coke Oven, and Raw Materials Conference.

The success of the H-Iron process depends upon several factors: an economical source of high-purity hydrogen . . . ability to transport particles by a gaseous medium from one container to another . . . and reduction of iron oxide at sufficiently high pressure and low temperature so that sintering of the particles to each other or to the container is avoided. Iron oxide is reduced with hydrogen in a fluid bed at a temperature less than 1000°F and at a pressure approximating 500 psi. The high operating pressure, which is the principal departure from other fluidizing processes, permits a high rate of reduction at low temperatures.

The Alan Wood iron powder plant is composed of four interrelated sections:

1) Iron ores are prepared for reduction in the raw materials preparation section;

2) Hydrogen, the reducing agent, is processed from coke-oven gas and oxygen in the hydrogen production unit;

3) The ore and hydrogen are chemically reacted in the H-Iron reduction section to produce metallic iron; and

4) The metallic iron is further processed in the finishing plant.

The reduction section performs a singular job, namely it removes oxygen from the ore to produce metallic iron. Unlike the blast furnace, the reducer does not eliminate gangue or waste material from the ore. Therefore, to produce metallurgical-grade iron powder, the ore must be free or nearly free of materials other than iron oxide.

Raw materials preparation

Two sources of iron oxide are being utilized at the present time: high-grade magnetite and mill scale from rolling-mill operations. The preparation of raw materials is performed in two widely separated plants.

At the Scrub Oaks mine, the high-grade magnetite concentrate containing 99 pct Fe_3O_4 is dried in

a rotary dryer, loaded in covered hopper cars, shipped to the iron powder plant at Conshohocken, and transferred to storage.

Equipment has also been installed at the Conshohocken plant for the preparation of mill scale or other ores, and for the re-treatment of the high-grade concentrate, if deemed necessary. Materials can be received by rail or truck, dried in a rotary drier, magnetically separated to remove waste material, and ground to a predetermined particle size in a ball mill operated in closed circuit with a classifying system. The product from this section is delivered to storage to await further processing. Typical size distribution of concentrates is essentially between 20 mesh and 200 mesh and that of mill scale — 80 mesh.

Hydrogen production

Hydrogen for the reduction of the iron oxides is produced by a partial oxidation process. The versatility of the process allows for the production of hydrogen in large quantities at low cost from the most common fuels. At Alan Wood, hydrogen is made from coke-oven gas, consisting of about 55.4 pct H_2, 28.4 pct CH_4, 4.3 pct N_2, 1.4 pct CO_2, and 3.3 pct other hydrocarbons. The methane and other hydrocarbons are converted to hydrogen by burning with oxygen in a fuel-rich mixture under pressure. The resulting raw gas is subjected to a water shift reaction and final scrubbing. The oxygen for the reaction is obtained from an adjacent low-temperature air-separation plant, which also supplies oxygen to the company's steelmaking operations. The basic reactions of the partial oxidation process are:

$$CH_4 + \tfrac{1}{2}\ O_2 \rightarrow CO + 2\ H_2$$
$$CO + H_2O \rightarrow H_2 + CO_2$$

Coke-oven gas is received at 3 psi, compressed to about 500 psi by a four stage compressor, and delivered to the partial oxidation generator along with 500 psi 98 pct O_2. Sufficient oxygen is supplied to burn the hydrocarbon components of the gas to H_2 and CO, as indicated by the first reaction. If complete combustion were permitted, the ultimate products would be H_2O and CO_2. The reaction is controlled primarily by maintaining the optimum reaction temperature and minimum quantities of hydrocarbons and carbon dioxide in the product gas. The latter is determined automatically by an instrument functioning on infrared principles. The carefully-controlled reaction produces the desired products of H_2 and CO, which are shifted to additional hydrogen in the shift converter.

Prior to the shift conversion, the generator effluent gas, containing about 68 pct H_2 and 26 pct CO (dry basis), passes into the bottom of a saturator tower, where countercurrent streams of water saturate the gas with water vapor. The saturated gas leaves the top of the tower and is delivered to the shift converter through a heater for preheating to the temperature necessary for conversion.

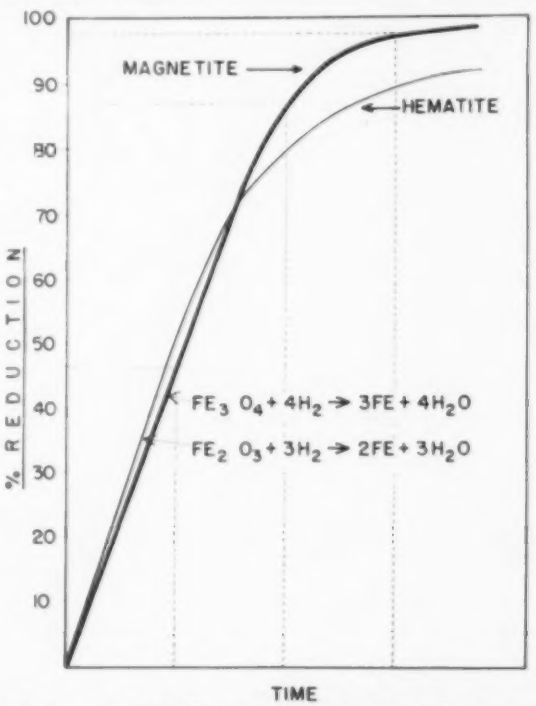
In the shift converter the gas mixture passes down through a catalyst which causes the CO and water vapor to react in a water-gas shift reaction to CO_2, as shown by the second reaction. The ratio of water to CO, the temperature, and the pressure are controlled to obtain the optimum conversion. The effluent from the converter contains about 75 pct H_2, 20 pct CO_2, 2 pct CO, and 3 pct N_2 (dry basis).

The H_2 must be nearly free of carbon oxides in order to minimize the subsequent synthesis of CH_4 in the ore reduction vessel by the catalytic action of the reduced iron. The CO_2 is removed first from the H_2 gas by absorption in aqueous monoethanolamine (MEA). The product gas emerging from the shift converter is cooled and delivered to the bottom of the CO_2 absorber. Rising through the tower countercurrent to the descending stream of MEA, it gives up essentially all of its CO_2 and any H_2S that might have been present.

The MEA solution containing the absorbed CO_2 leaves the bottom of the absorber and is delivered to the top of the MEA actifier tower. As the solution descends through a bed of raschig rings, the CO_2 is stripped free by steam ascending from a reboiler section at the base of the tower. The MEA leaves the actifier free of the CO_2, is cooled with water, and is pumped to the top of the CO_2 absorber, completing its circuit. The CO_2 leaving the top of the actifier is used for purging purposes in the reduction section of the plant.

Similarly, CO is removed from the product gas. Leaving the top of the CO_2 absorber, the gas with less than 0.1 pct CO_2 is compressed to approximately 700 psi, cooled, and delivered to the bottom of the CO absorber. The rising gas is countercurrently contacted by a descending solution of copper ammonium acetate (copper liquor) which absorbs nearly all the CO.

The solution, rich in carbon monoxide, leaves the bottom of the CO absorber, enters a regenerator where CO is released by reboiling. The copper liquor is cooled and returned to the top of the CO absorber to complete its circuit. The CO leaving the top of the regenerator is injected into the fuel gas system for the ultimate recovery of its heating value. The effluent from the CO absorber is the hydrogen product gas which contains essentially



Reduction rates attainable in the three beds of the H-Iron process with a residence time of 4½ hr in each bed.

96 pct H_2 and 4 pct N_2. The nitrogen enters the process at the generator as a contaminant in both the coke-oven gas and oxygen and remains unchanged throughout the process.

Fluid bed reduction

Iron ores relatively free of inert materials and ground to the desired particle size are delivered from the raw materials preparation section to the 95-ft high, 5½-ft diam H-Iron reduction tower. Reduction is achieved by processing the ore in a semi-batch process in three fluidized beds. In the reduction vessel the ore is countercurrently contacted with hydrogen gas at a temperature of less than 1000°F and at a pressure of approx 500 psi.

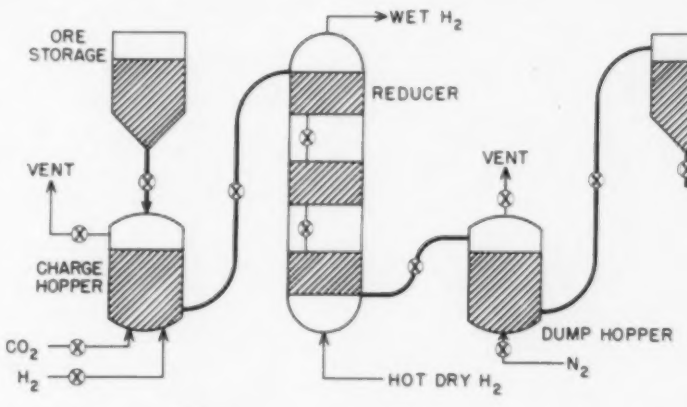
Three reducer beds are required for efficient operation, due to the decline in the rate of conversion as the reduction proceeds. The total time required to reach 98 pct reduction is divided into three equal intervals of about 4½ hr, representing the residence time for the material on each bed of the reducer. Elapsed bed times are such that about 47 pct reduction takes place on the first bed, proceeding to 87 pct on the second, and finally to the desired 98+ pct on the third bed.

Flow of solids

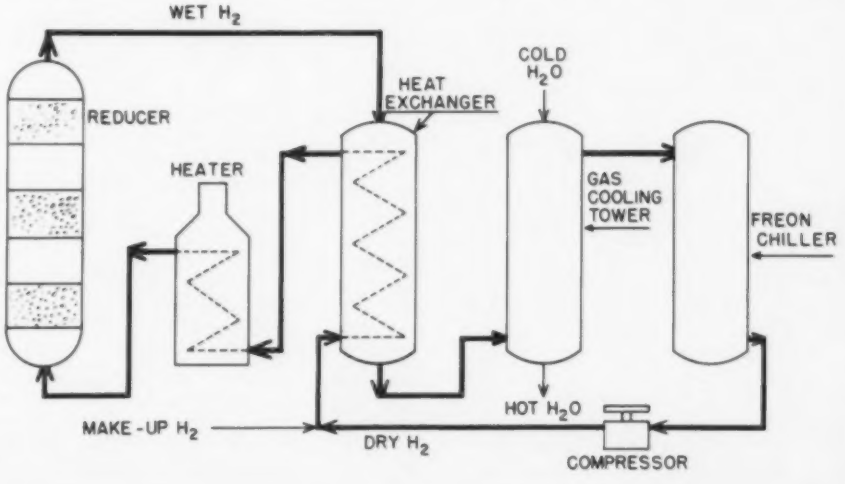
For ease in understanding the reduction section, the process flow is divided into two interdependent circuits. Iron ore sufficient to fill a single bed in the reducer is delivered to a charge hopper. The hopper is valved off from the ore supply and purged of air by the introduction of CO_2, a byproduct of the hydrogen production section. After purging, the hopper is valved off from the CO_2 and then pressured by a slipstream from the hydrogen circuit. When the pressure in the hopper is about 150 psi higher than in the reducer, the contents of the hopper is delivered through a 1½-in. pipe to the top bed of the reducer by merely opening a valve in the line. The 1½-in. line transfers 15 tons in about 10 min.

Before the reducer can receive a batch of ore from the charge hopper, the iron at the desired degree of reduction on the bottom bed is delivered by pipeline to the dump hopper. The partly-reduced material on the second bed is then discharged through internal valves to the bottom bed and the least reduced material on the top bed is likewise dumped to the second bed. The batch of ore in the charge hopper is then transferred to the top bed of the reducer. The charge hopper is later valved off from the reducer, depressurized, and readied for another cycle. During the transfers, the reduction vessel remains at full pressure, with fluidization and the flow of hydrogen through the reducer uninterrupted.

The dump hopper containing the reduced iron is depressurized and purged of hydrogen with nitro-



Solids circuit of the H-Iron process.



Gas circuit for H-Iron reduction.

gen, a byproduct of the oxygen plant. The H-Iron is then conveyed by pipeline to a storage bin and maintained in the nitrogen atmosphere until ready for final processing in the finishing section. Storage under nitrogen is necessary at this point, since the H-Iron is pyrophoric and cannot be exposed to air.

Flow of gases

Dry hot H_2 enters the base of the reducer and passes up through the three fluid beds in series. The velocity of the gas through the finely-ground ore is maintained at a rate higher than that required to make the material buoyant. This produces bubbles which cause violent agitation of the solids and provides excellent contact between reducing gas and ore. Approximately 5 pct of the hydrogen is converted to water and leaves the top of the reducer with the unreacted hydrogen.

The effluent from the reducer is partially cooled in an exchanger, while preheating the incoming dry H_2 to the reducer. Next, the gas passing up through a cooling tower is cooled to about 90°F by a descending stream of cooling water. Further cooling of the gas stream to about 55°F is accomplished in a freon chiller. Cooling in this manner at the high operation pressure reduces the water content in the hydrogen to only a few hundredths of a percent.

A portion of the hydrogen stream, vented off to prevent the accumulation of inert gases, is injected into the fuel gas system for the ultimate recovery of its heating value.

The major portion of the dry H_2 recovers its pressure losses in a recycle compressor and is then joined by a make-up H_2 stream from the hydrogen production unit. The combined streams are preheated in the heat exchanger while cooling the effluent from the reducer; they enter a gas-fired heater where they are heated to about 1000°F, and finally return to the reducer to complete the circuit.

Finishing plant

The additional processing necessary to produce metallurgical grades of iron powder is performed in the finishing section of the plant. The product from the H-Iron reduction section, kept in a nitrogen atmosphere to prevent immediate reoxidation by air, need only be raised to a temperature of 1500° to 1600°F in order to render it non-pyrophoric. To accomplish this passivation phase, the H-Iron is loaded in pans and thence into a roller hearth furnace, heated to the desired temperature, and finally cooled to room temperature in a water-cooled zone of the furnace. The entire operation is performed in a nonoxidizing atmosphere.

The stabilized product emerging from the furnace is then treated to produce iron powders for various applications. Control of the several properties of the powders is accomplished by a flexible flow of the material through equipment designed to adjust particle size, bulk density, compactibility, green strength, tensile strength, etc. The finished iron powders are blended to assure proper particle size distribution and finally packaged according to customer specifications. Additives may be included during the blending operation to supply the customer with pre-mixed powders of various grades.

Table I. Typical Composition of Various Powder Grades, Pct

Element	Molding Powder	Electrode Coating Powder	Melting Stock
Total Fe	98.80	96.5 -97.5	96.5 - 97.5
Metallic Fe			95 - 96
Hydrogen Loss	0.63	0.50	
C	0.02 -0.10	0.013	0.013- 0.04
P	0.007-0.018	0.008- 0.01	0.008- 0.01
S	0.021	0.005- 0.02	0.005- 0.02
Mn	0.43	0.02 - 0.10	0.02 - 0.10
SiO_2	0.20	0.5 - 1.0	0.5 - 1.0
Cu			0.01 - 0.02
Mo			0.01 - 0.02
V			0.01 - 0.02
Ni			0.01 - 0.02
Ca			0.01 - 0.02
Bi			0.001- 0.002
Sn			0.001- 0.002
Pb			0.001- 0.002
Cr			0.001- 0.002
Co			0.001- 0.002
Al_2O_3			0.2 - 0.4
TiO_2			0.3 - 0.6
MgO			0.08 - 0.1

Consuming industries

Iron powder has a variety of uses, but the larger tonnages presently go into the manufacture of molded mechanical and structural parts, welding rod coatings, metallic-type friction materials, electrical cores and magnets, and into powder cutting and scarfing applications.

A mechanical part made of iron powder is manufactured by pouring the powder into a die and pressing it to shape. The part is then sintered, which causes the particles to bond together and form material with strength approaching that of wrought metal of similar alloy. Savings in the use of metal powder parts result mainly from the elimination of expensive machining which is necessary when parts are made by normal manufacturing methods. Also, metallurgists can do many things with powder that cannot be done with regular metals. For example, it is possible to control the porosity of parts to be used in self-lubricating bearings and filters.

Welding costs today are lowered by the higher welding speeds achieved through the use of iron-powder-coated electrodes. The welding industry looks to these rods as a new and important step in its field. Powder cutting and scarfing, a process in which iron powder is fed into an oxygen-cutting flame, is still another use. It is used to burn through high temperature alloy steels, cast iron, certain refractories, and concrete. In a relatively few years, powder cutting has earned an important place in mills, foundries, warehouses, fabricating plants, and oil refineries.

Although the plant was primarily constructed for the production of iron powder for the powder metallurgy industry, other possibilities were considered. Equipment was installed to briquette the iron powder to produce various types of melting stock. Briquettes are formed with or without carbon, and also without residual metals for special applications.

These briquettes will be marketed for use in open-hearth, electric, and induction furnaces. A special grade of melting stock is being developed for vacuum melting.

It is also our intent to determine the practicability of utilizing partially-reduced H-Iron for replacing purchased scrap and ore in the open hearth, and the H-Iron process in conjunction with electric furnaces for the future expansion of steelmaking capacity.

We at Alan Wood believe that the new powder plant will contribute much to the advancement of powder metallurgy and also provide information that might eventually lead to a versatile process of smaller capital cost for the production of steel.

HOW OXYGEN INPUT AFFECTS OPEN-HEARTH STEELMAKING

"How fast and at what cost can open-hearth steel be made?" This paper provides a partial answer by discussing the chemical and thermal effects of using high oxygen input rates from the time hot metal has been added until the furnace is ready to tap.

by A. L. Hodge and C. S. Arnold

OVER 100 years ago, Bessemer and Kelly were among the first to show the extremely fast reaction rates possible with direct oxidation methods. Since World War II, a great deal of study and development has been devoted to the use of oxygen in the open hearth to speed chemical reaction rates. Oxygen used in this way can indeed be considered revolutionary since, in many cases, it has changed the ordinary open hearth to practically a pneumatic operation.

One of the early uses for oxygen in the open hearth was to remove carbon during the work period. When oxygen was used for this purpose, two important effects were observed apart from the rapid rate of carbon oxidation: first, extreme agitation of bath and slag resulted in more uniform chemical control with a more consistent approach to equilibrium; secondly, a large amount of high-temperature heat was made available to the bath.

To make maximum use of these observations, several fundamental aspects were investigated. These included the chemical distribution of oxygen and the actual amount of heat produced and absorbed during oxygen injection. Various consumable and non-consumable injection devices, oxygen flow rates, and methods of injecting oxygen were also investigated and reported.

Conclusions reached during work carried out from 1945 to 1952 are published in an earlier report.[1] Several of these conclusions are of paramount importance and may be restated as follows:

1) The mechanism of carbon oxidation in the open hearth can be expressed by three primary chemical reactions occurring simultaneously: carbon oxidation, iron oxidation, and oxygen in solution. The extent to which each reaction proceeds will depend primarily on the carbon content of the bath, slag conditions, and the method of oxygen injection.

[1] A. L. Hodge: Some Aspects on the Mechanism of Oxidation in the Open Hearth Furnace, *Iron and Steel Engineer*, vol. 35, pp. 95 to 100, November 1959.

A. L. HODGE and C. S. ARNOLD are at the Development Laboratory of Linde Co., div. of Union Carbide Corp., Newark, N. J. This paper was presented at the 1960 AIME Annual Meeting.

2) Each reaction in conclusion 1 will exert a different thermal effect.

3) With proper injection techniques the chemical reacting efficiency of oxygen averages 90 pct or more.

4) The distribution of total oxygen consumed in burning carbon or entering solution in the iron and slag can be predicted fairly closely, depending on conclusions 1 and 3; however, every source of oxygen must be taken into account.

Oxygen sources and distribution efficiency

To produce 1 ton of low-carbon, basic-open-hearth steel with a 65 pct hot-metal charge requires about 150 lb of total oxygen, equivalent to about 1800 cu ft. It will be supplied from all sources including ore, limestone, atmosphere, and gaseous oxygen. Removing only the carbon and neglecting other reactions will require about 70 lb of oxygen or 850 cu ft. From this, it might be assumed that the oxygen efficiency is only about 45 pct, but this would be erroneous since other oxidation equilibria must be satisfied. Hence, more accurate terms in place of *efficiency* would probably be *chemical reactive efficiency* and *oxygen distribution*. The first term is a measure of the total oxygen absorbed by the bath and slag; the second measures the fractions of oxygen entering various chemical reactions.

To cite an example, it was stated earlier that, with proper operating practice, the chemical reactive efficiency of oxygen is 90 pct or more. Thus, from earlier measurements Table I shows the oxygen distribution at various carbon contents for a specific slag practice. The importance and value of these distribution quantities cannot be overemphasized. They provide the characteristic *bends* and limitations to the time-rate curves when plotting carbon content vs time for any specific oxygen input rate. It should be further emphasized that the above values pertain to specific slag conditions and hot-metal silicon and phosphorus contents of about 1.0 pct and 0.25 pct, respectively. Hence, if greater slag volumes are used a greater amount of oxygen (and iron as FeO) will be absorbed by the slag. Such losses will be very significant at carbon con-

tents of about 0.12 pct and less, when the amount of oxygen absorbed by the slag is well over 50 pct. In actual practice, an additional 100 lb (per ton of ingot) slag with a basicity of 3.0 and a FeO content of 20 pct will represent a loss of about 16 lb of iron and 54 cu ft of oxygen per ton. This iron loss would decrease the conversion yield by 0.8 pct.

Table I. Distribution of Total Oxygen Reacting at Various Carbon Contents

Slag Conditions: 170 lb per ton; $\frac{CaO}{SiO_2} = 3.0$

C Content, Pct	Total Oxygen Reacting, Pct		
	$O_2 \rightarrow CO$	$O_2 \rightarrow FeO_{slag}$	$O_2 \rightarrow O_{steel}$
2.00	95	5	nil
1.00	95	5	nil
0.50	85	14	1
0.30	80	18	2
0.20	65	30	5
0.10	35	56	9
0.08	25	65	10
0.06	18	70	12
0.03	5	85	10

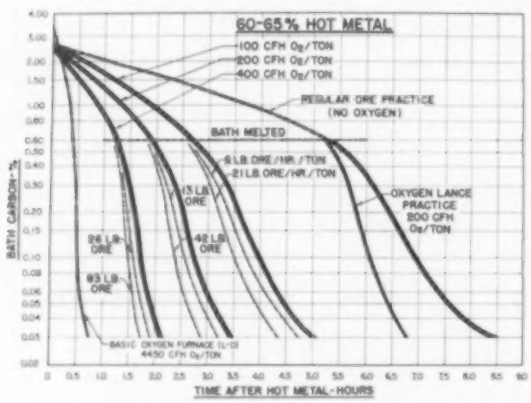


Fig. 1—Hot metal-to-tap time at varying oxygen flows to reduce carbon with ore added to absorb heat—60 to 65 pct hot metal.

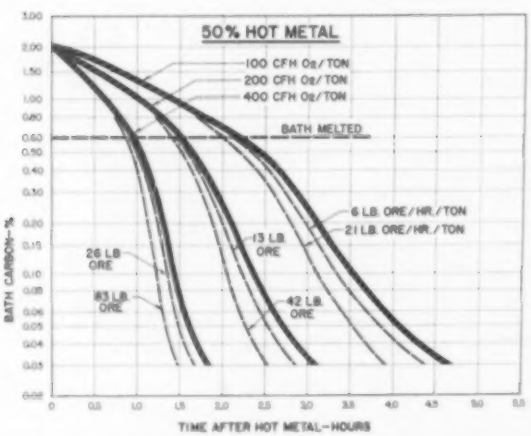


Fig. 2—Hot metal-to-tap time at varying oxygen flows to reduce carbon with ore added to absorb heat—50 pct hot metal.

Excessive silicon contents contribute to iron and oxygen losses, since only 0.1 pct Si requires about 28 cu ft of oxygen per ton for oxidation and the resulting silica absorbs about 7 lb of iron oxide per ton for fluxing and runoff. Oxygen required for phosphorus oxidation amounts to about 31 cu ft per 0.1 pct P per ton of hot metal. Another relatively common cause for excessive iron and oxygen losses results from injecting oxygen into the slag with insufficient momentum.

Of equal or greater importance than the distribution quantities of oxygen reacting, is the matter of total oxygen supplied to the bath. This will, in large part, determine how fast an open hearth can be operated. Oxygen is supplied from several sources, and all must be taken into account. For example, the initial charge will often contain several thousand pounds of ore or sinter which contain 25 to 30 pct O_2 by weight. Similarly, limestone contains about 15 pct of equivalent available oxygen. Finally, to provide the high production rates desired and to supply concurrently the large amounts of high-temperature heat required, gaseous oxygen may be injected from the time hot metal has been added until the heat is ready to tap. Oxygen injection rates under these conditions have steadily increased to 100,000 cfh and higher. To help control heat input with high oxygen flow rates after the bath is completely melted, intermittent additions of good-grade feed ore are recommended. Besides controlling temperature, the ore in this case is a good source of iron and oxygen.

The open-hearth furnace is extremely oxidizing because of the large mass of combustion gases passing over the bath each hour. In actual practice, the weight of gases flowing through the furnace per hour may equal as much as 1/2 to 1/3 of the total furnace charge weight. Thus, to show the relative magnitude of the amounts of oxygen available from various sources cited here, Table II shows carbon content vs oxygen quantities expressed in cfm during the course of a 300-ton heat. The initial charge contained 65 pct hot metal, with standard amounts of ore and limestone; oxygen was injected at a rate of 60,000 cfh from hot metal addition to tap. Feed ore was added at a rate of 12,600 lb per hr after the bath was melted in order to absorb 65 pct of the oxidation heat.

An analysis of data in Tables I and II leads to certain conclusions: 1) the total oxygen from all sources absorbed by the charge can be estimated and controlled within fairly close limits at high production rates; and 2) the distribution of oxygen supplied to various oxidation reactions is thermochem-

Table II. Oxygen Available From Various Sources Versus Carbon Content For a 300-Ton Heat

C Content, Pct	Charge Ore, Limestone and Atmosphere		Injected O_2		Feed Ore		Total, = 100 Pct
	Cfm	Pct	Cfm	Pct	Cfm	Pct	Cfm
2.00	1500	60	1000	40	0	0	2500
1.00	600	37.5	1000	62.5	0	0	1600
0.50	435	21	1000	48	640	31	2075
0.20	390	19.5	1000	49	640	31.5	2030
0.10	390	19.5	1000	49	640	31.5	2030
0.05	330	16.7	1000	50.7	640	32.6	1970

ically related to bath carbon, slag conditions, and injection efficiency.

Based on this information, it is possible to calculate various relationships with fair accuracy, thereby relating variables such as production rates, carbon oxidation rates, oxygen consumption, and thermal effects to high oxygen input rates. In the LD vessel (basic oxygen furnace) these calculations can be made with relatively close accuracy, because all materials are accurately weighed or measured and there is no oxidizing atmosphere to evaluate.

Operation with high oxygen input

A primary objective of this paper is to describe several of the above relationships in terms of empirical data obtained from actual furnace tests. Thus, results shown graphically in Figs. 1 to 11 have been presented for hot metal charges of 50, 65 and 80 pct. Comparison of these results with actual furnace operation has been very satisfactory. In a few instances, significant deviations in oxygen consumption or a lower rate of carbon removal could be attributed to one or more of the following causes: a) an excessive decrease in the charged ore, b) high hot metal silicon and phosphorus, c) excessive additions of burnt lime or excessive slag volumes, d) improper oxygen injection, or e) improper fuel-air control.

Oxygen injection is practiced from hot-metal charge to tap at flow rates of 100, 200, 400, and 1000 cfh per ton. In a 300-ton furnace, these flow rates would correspond to 30,000, 60,000, 120,000, and 300,000 cfh. At the present time with the hundred or more furnaces equipped with roof jet injection devices, flow rates have been of the order of 125 to 200 cfh per ton. Experimentally, two or three times these rates have been tried. Theoretically, there is probably no particular limit to the oxygen input rate, although practical considerations impose limits, depending on factors such as materials handling, furnace and shop design, fume control, oxygen supply, and relative costs.

Figs. 1 to 11 show such general relationships as: 1) time required from hot metal to tap vs. carbon content for various oxygen flow rates; 2) oxygen consumption in cu ft per ton vs tap carbon and oxygen flow rate; 3) oxygen consumption in cu ft per ton per 0.01 pct C vs carbon content and oxygen flow rate; 4) rate of carbon oxidation, $\frac{-dC}{dt}$, vs carbon content and oxygen flow rate; 5) heat liberated during oxidation vs carbon content; 6) heat savings vs oxygen consumption; and 7) bath temperature vs oxygen injection.

High Production Rates

Fig. 1 shows the time required to reach tap carbon after hot-metal addition, using various oxygen flow rates for a hot-metal charge of 65 pct. This particular illustration might be considered the *blue print of a revolution* since it shows a number of striking situations. For example, the uppermost curve extending from 2.5 pct C and ending at a time of 8.5 hr represents what was considered as good open-hearth practice without oxygen during World War II. With a total charging time of 2 hr and a tap carbon of 0.10 pct, the charge-to-tap time would be about 9 hr (2 + 7 = 9).

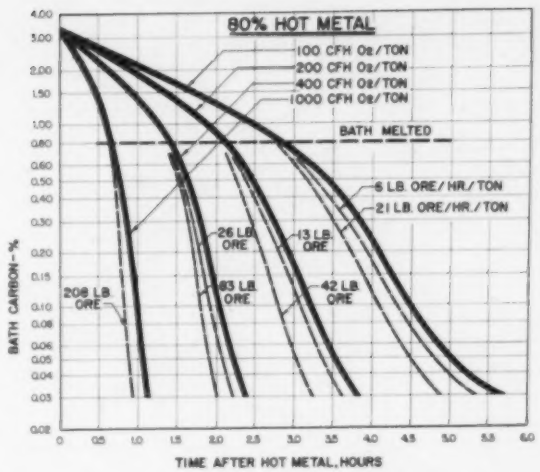


Fig. 3—Hot metal-to-tap time at varying oxygen flows to reduce carbon with ore added to absorb heat—80 pct hot metal.

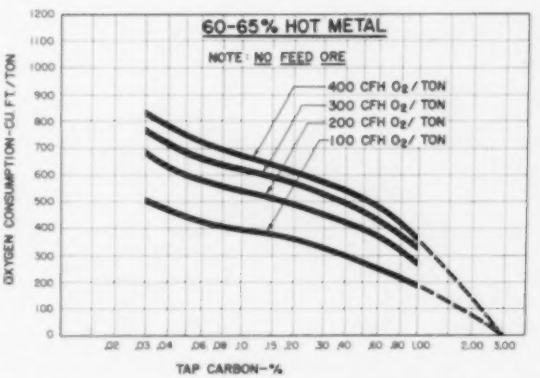


Fig. 4.—Oxygen consumption vs tap carbon and oxygen flows for 60 to 65 pct hot metal.

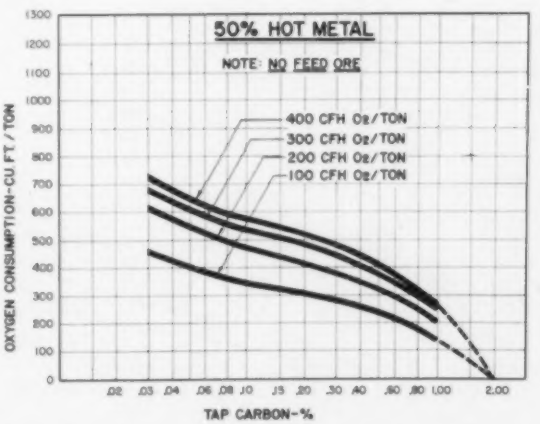


Fig. 5—Oxygen consumption vs tap carbon and oxygen flows for 50 pct hot metal.

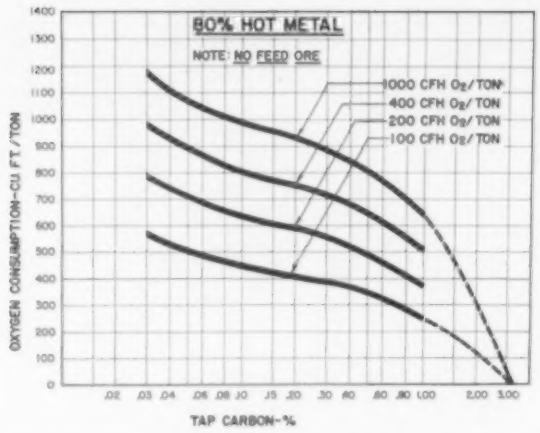


Fig. 6—Oxygen consumption vs tap carbon and oxygen flows for 80 pct hot metal.

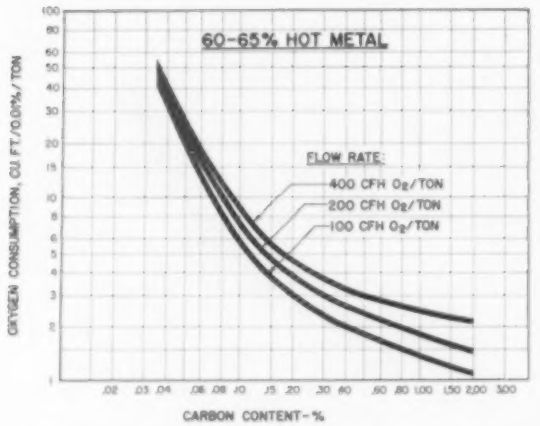


Fig. 7—Oxygen requirements to remove 0.01 pct C per ton vs carbon content.

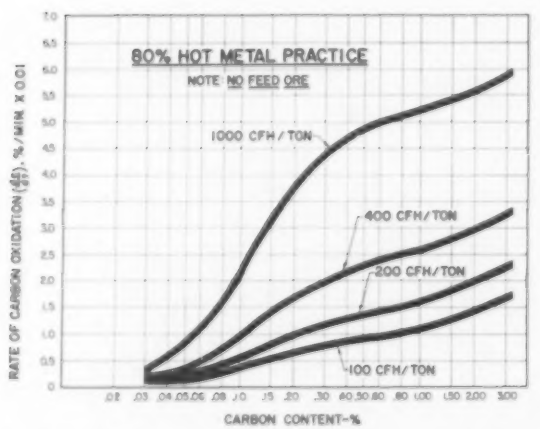


Fig. 8—Interrelationship between carbon oxidation rate, bath carbon, and oxygen input—80 pct hot metal practice.

To hasten this practice, oxygen can be injected after the bath is melted, as shown in the short curve beginning at 0.60 pct C and ending at about 6.75 hr. Oxygen used in this way at a flow rate of 200 cfh per ton will decrease the charge-to-tap time of the above heat to about 8 hr. The next curves to consider are those depicting the use of continuous oxygen injection from hot metal to tap carbon at flow rates of 100, 200, and 400 cfh per ton. As an example, a 300-ton furnace using an oxygen rate of 200 cfh per ton (60,000 cfh) would reach 0.10 pct C in about 2.75 hr after hot metal.

The ore addition curves beginning at 0.60 pct C show the effect of adding ore for controlling temperature, as discussed previously. The ore addition rate for each set of two ore curves corresponds to the amounts of ore required to absorb 20 and 65 pct of the heat liberated in direct oxidation. Furthering the example with an oxygen input of 200 cfh per ton, to absorb 65 pct of the heat would require 42 lb of ore per hr per ton, or about 12,600 lb of ore per hr. With this ore addition, the heat time would be decreased by another half hour, and about 3,700 lb of iron would be added to the heat along with about 1800 lb of oxygen (20,000 cu ft) over a period of 30 min. Of course, the extent to which ore additions can be made will depend on furnace conditions and to a large degree on the price and quality of feed ore available. Under the above conditions, a charge-to-tap time of the order of 5 hr or less is feasible, as has been demonstrated in actual practice; this is shown in Table II.

To extend the *revolution* further, the curve at the extreme left of Fig. 1 represents an oxygen input rate of 4450 cfh per ton in an LD vessel. In a 100-ton vessel, the flow rate would amount to 445,000 cfh or about 7400 cfm. This is not uncommon practice in American LD shops. However, this is not to suggest that open-hearth furnaces are to be made into LD vessels. Nevertheless, the comparison indicates how the present open hearth may be considered as rapidly approaching a pneumatic process. Oxygen for combustion has not been mentioned, since oxygen used in this way would have its greatest effect prior to the hot metal addition.

Figs. 2 and 3 are similar to Fig. 1, except that the hot metal charges are for 50 and 80 pct, respectively. A rapid comparison of Figs. 2 and 3 might suggest that shorter heat times could be made with a 50 pct liquid metal charge than with 80 pct. However, the curves shown apply only to oxidation time after hot metal; in this instance, final production rates may depend as much or more on charging time.

Referring to Fig. 3, an 80 pct hot-metal charge requires 3.2 hr to blow the heat down to 0.10 pct C with an oxygen input of 200 cfh per ton. For 50 pct hot metal in Fig. 2, 2.3 hr are required to reach the same tap carbon with the same injection rate. Although there is a time difference of 0.9 hr in favor of the 50-pct hot-metal charge, the total charging time for the 80-pct charge could be shorter by more than the 0.9 hr difference. Furthermore, there is a strong chance that higher injection rates would be more desirable and more feasible with the higher hot-metal charges. For this reason, Fig. 3 includes an oxygen flow rate of 1000 cfh per ton. With this injection rate, 0.10 pct C could be reached in 1 hr. Assuming a total charging time of 1 hr, another 30 min for adjustments would result in a charge-to-tap time of 2.5 hr. In a 300-ton furnace this would re-

quire a total oxygen flow rate of 300,000 cfh, which could conceivably result in a normal tap-to-tap production rate of 90 to 100 tph. This could be considered either a modified LD-type operation or a *revolutionary* open hearth.

Oxygen Consumption

Fig. 4 shows the amount of oxygen required when blowing a heat down to any tap carbon from an original carbon content corresponding to 60-65 pct hot metal. Other conditions for which these curves apply are: 1) Standard ore and limestone charges; 1.0 pct Si and 0.25 pct P hot metal; 2) No feed ore additions; and 3) A slag volume of about 200 lb per ton.

In actual practice, these curves agree quite closely, except where significant decreases were made in original charge ore, or in using heavy feed-ore additions, improper jet operation, or with high slag volumes. In studying the curves representing different oxygen flow rates, the increase in oxygen consumption with higher flows is due to a lessening effect of the inherent oxidizing characteristics of the open hearth with greater production rates.

To explain these variations in oxygen consumption, let us refer to Fig. 1 using flow rates of 100 and 400 cfh per ton and tapping 0.10 pct C. The corresponding blowing times are 3.9 and 1.7 hr, respectively. From Fig. 4, the corresponding oxygen consumptions are 390 and 670 cu ft per ton, respectively. From these results it could be assumed that, with the lower oxygen flow rate and longer heat time, the bath absorbed 280 cu ft of oxygen per ton from the furnace atmosphere during the 2.2 hr longer heat time. An additional example of higher oxygen consumption would be the case of blowing the 80 pct hot metal charge with 300,000 cfh oxygen. Here the oxygen consumption would amount to approximately 1000 cu ft per ton (Fig. 6). Figs. 5 and 6 are similar to Fig. 4 referring to hot metal charges of 50 and 80 pct, respectively.

Fig. 7 is another interesting relationship of oxygen consumption. In this case, it represents the amount of oxygen required to remove 0.01 pct C per ton of steel. This quantity of carbon amounts to 0.2 lb which, when oxidized to carbon monoxide, theoretically requires 3.2 cu ft of oxygen. However, the curves indicate that the actual amount of oxygen required may vary from 1.1 to 50 cu ft. The reasons for this large variation are, again, due to oxygen being supplied by other sources and the wide range of percentages of total oxygen reacting with carbon over the entire range of high to low carbon contents. At the low carbon contents, such as at 0.03 pct, Table I shows that only about 1/20th of the oxygen reacts with carbon. This corresponds to the oxygen volume ratio of about 50:3.2 at 0.035 pct C in Fig. 7. Probably the most obvious feature about this oxygen consumption relationship is that it shows that little significance should be attached to the simple estimating expression of *cu ft of oxygen per ton point* unless a definite carbon working range is specified.

Rate of Carbon Oxidation

Of particular interest is the instantaneous rate of carbon oxidation sometimes referred to as the differential rate and expressed as $\frac{-dC}{dt}$. Fig. 8 shows how the carbon oxidation rate varies with bath

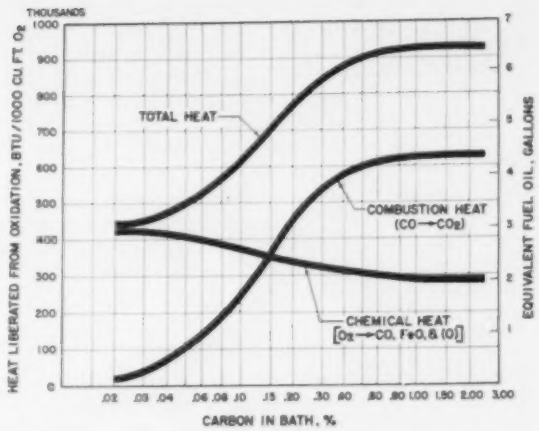

THOUSANDS
HEAT LIBERATED FROM OXIDATION, BTU/1000 CU. FT. O2
EQUIVALENT FUEL OIL, GALLONS
TOTAL HEAT
COMBUSTION HEAT (CO→CO2)
CHEMICAL HEAT [O2→CO, FeO, & (O)]
CARBON IN BATH, %

Fig. 9—Relationship between carbon content and heat liberated per 1000 cu ft of injected oxygen.

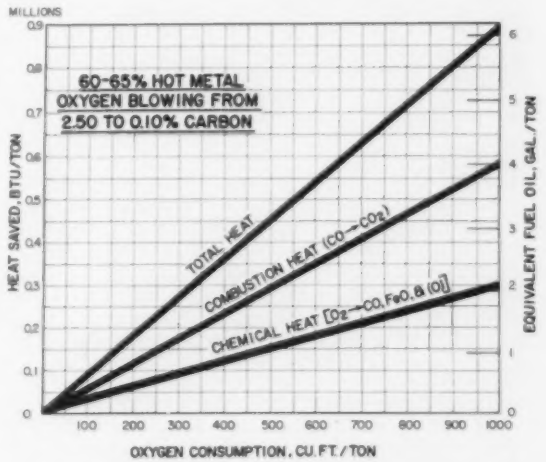


Fig. 10—Heat savings associated with oxygen consumption when blowing 60 to 65 pct hot metal from 2.50 to 0.10 pct C.

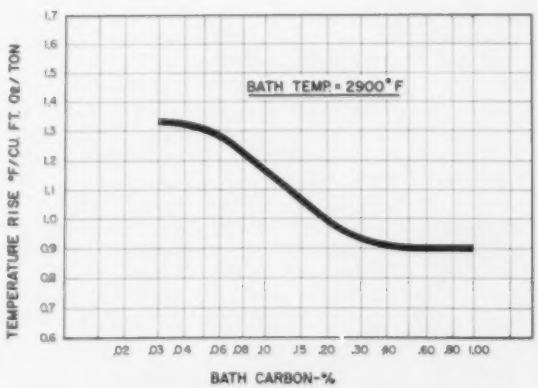


Fig. 11—Effect of oxygen injection on bath temperature vs carbon content.

carbon and oxygen input. Although the plots are designated for 80 pct hot metal, they apply for any lower hot-metal charges, since the differential rate of carbon oxidation is not dependent to any significant extent upon the initial carbon content of the charge. Instead, it depends primarily on the instantaneous conditions existing at any carbon content in question.

It is interesting to note the rapid convergence of all the oxidation curves, irrespective of oxygen flow, in the region of 0.03 to 0.05 pct C. This area would correspond to the typical *end point* or *flame drop* in a bessemer or LD blow.

Thermal Effects

In any direct oxidation of iron or steel with oxygen, a large amount of reaction heat is liberated. As mentioned earlier, three primary reactions may occur during carbon oxidation, with each liberating a different quantity of heat. These reactions are shown below with the amounts of heat resulting from 1 cu ft of reacting oxygen; in addition, the reaction for silicon oxidation which takes place early after the hot-metal addition is also shown:

Reaction	Heat Liberated per cu ft O_2
a) $C_{(in\ Fe)} + \frac{1}{2}O_2 = CO$	326 Btu
b) $Fe + \frac{1}{2}O_2 = FeO_{(slag)}$	516 Btu
c) $O_2 = 2[O]_{(in\ Fe)}$	247 Btu
d) $Si_{(in\ Fe)} + O_2 = SiO_2$	928 Btu

The total amount of available heat will depend, first of all, upon the quantity of oxygen entering into each of the above reactions. This total reaction heat may be considered as the heat of direct oxidation and is extremely effective, because its heat transfer efficiency may be as high as 80 pct or more. Another large source of heat is derived from the combustion of the carbon monoxide (Reaction a) with excess furnace air.

Fig. 9 shows the relationship between carbon content and the amount of heat liberated per 1000 cu ft of injected oxygen*. Referring to an earlier example using 60,000 cfh of oxygen, at 1.00 pct C the heat available from direct oxidation would amount to about 17.5 million Btu per hr. If the carbon monoxide is burned to the dioxide, another 37.5 million Btu per hr will be available. The total heat in this case resulting from oxygen injection would amount to 55 million Btu per hr or an equivalent of about 380 gph of oil. Continuing the example with the same oxygen input but estimating the available heat at 0.05 pct C, the heat of direct oxidation would equal 24 million Btu per hr, while 6 million Btu per hr would result from burning the carbon monoxide to dioxide. This would make a total of 30 million Btu per hr or an equivalent of about 210 gph of oil. Thus, from these examples, two important conclusions can be drawn: 1) a large amount of high-temperature heat is available during direct oxidation. This heat should be compensated for in firing rates to avoid furnace refractory damage; and 2) to obtain maximum thermal benefits from oxygen injection, proper proportioning of air should be made to burn all the carbon monoxide.

* In calculating the heat quantities for Figs. 9-11, the direct oxidation heat of silicon shown in reaction d was not included because it was felt that the major oxidation of silicon took place with liquid iron oxide.

Fig. 10 is another thermal relationship showing possible heat savings vs oxygen consumption when blowing a 65 pct hot-metal charge to 0.10 pct C. Again, this graph shows the heat from direct carbon oxidation, the heat from burning CO to CO_2, and the total heat available. (The heat of direct oxidation of silicon is omitted.)

Examples show that, if good combustion control is practiced with an oxygen consumption of 600 cu ft per ton, a heat saving of about 540,000 Btu per ton is obtained. This is equivalent to about 3.7 gal of oil per ton. However, if the carbon monoxide is not completely burned, the heat saving may be as little as 180,000 Btu per ton, or only about 1¼ gal of oil per ton. In actual practice, the maximum savings shown in Fig. 10 may be significantly larger, since major savings in fuel consumption are possible due to shorter heat times.

Fig. 11 shows the effect of oxygen injection on bath temperature vs carbon content. The ordinate is expressed in a temperature rise of °F per cu ft of O_2 per ton of steel. This graph is particularly worthwhile when using oxygen to increase bath temperature. Although this curve is based on theoretical values, agreement of the data were very satisfactory during actual tests in open hearths and in large electric furnaces. From this plot, an injection rate of 60,000 cfh of oxygen in a 300-ton heat and firing the furnace for constant temperature would increase bath temperature at the rate of about 200°F per hr or about 3.3°F per min.

Summary

Oxygen has revolutionized open-hearth practice by converting it to practically a pneumatic operation. By using high oxygen flow rates from hot metal to tap, production rates of 90 to 100 tph are conceivable in a 300-ton furnace. Oxygen consumption under these conditions ranges from 600 to 1000 cu ft per ton. However, if the full benefits of oxygen are to be realized certain fundamentals must be borne in mind. These are:

1) The importance of thermochemical effects involving oxygen;

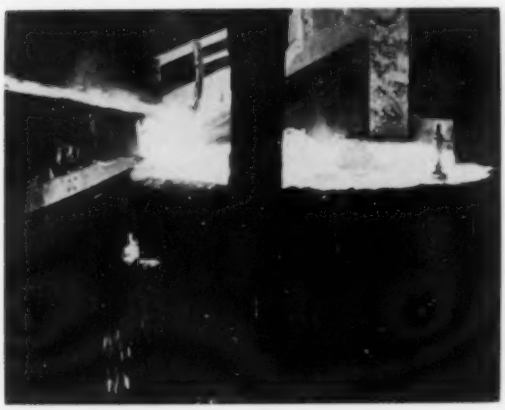
2) Realization that operating speeds with an open hearth are a) dependent upon oxygen as supplied from all sources, (such as the ore, the atmosphere, and injection), and b) dependent upon how oxygen distributes itself as a reactant in the bath;

3) Recognition of the importance of burning all carbon monoxide to carbon dioxide;

4) Need to control slag volumes so as to minimize oxygen and iron (FeO) losses to the slag.

When these fundamentals are observed, the use of oxygen for rapid carbon oxidation in turn leads to more uniform control of both chemical reactions and a greater degree of high-temperature heat availability. Furthermore, the chemical reaction efficiency of oxygen averages 90 pct or more with proper injection technique. Finally, as demonstrated in actual furnace tests, it becomes entirely possible to predict specific oxygen input rates to achieve specific end results as desired.

FACTORS AFFECTING TEMPERATURE DROP BETWEEN TAPPING AND TEEMING



Quantitative relationships among the factors which affect temperature variations between furnace tapping and teeming are analyzed, and a procedure is developed for determining the probable temperature change.

by N. L. Samways and T. E. Dancy

ONE of the most important factors affecting the manufacture of consistently good steel ingots is the control of teeming temperature. It is well established, for example, that teeming temperature can be associated with ingot cracking, ingot structure, ingot segregation, and, in the case of rimmed steel, the rimming action in the mold. However, the control of furnace tapping temperature alone is not sufficient to ensure that the correct ingot teeming temperature is obtained.

In this paper an attempt has been made to relate, quantitatively, the factors which affect temperature variations between furnace tapping and teeming, and to indicate a procedure by which the probable temperature change can be determined. The method has been developed from detailed statistical analyses of measured tapping and teeming temperatures in open-hearth and basic-oxygen (LD) shops, together with heat balance calculations of the effect of ladle additions and an independent theoretical treatment of heat losses to ladle walls.[1] In all, 73 open-hearth and 25 basic-oxygen heats were examined covering all grades of steel. Although no

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measurements were taken in an electric furnace shop, the method developed for estimating temperature drop is of general application to all types of furnace or steel composition and should, therefore, be of value to electric furnace steel works.

The main variables that have been considered in determining the temperature drop between tapping and teeming are:

1) Bath temperature at the end of refining;
2) Steel bath carbon, manganese, and oxygen level;
3) Character of tapping stream and tapping time;
4) Ladle and furnace additions;
5) Ladle refractory temperature;
6) Holding time, and
7) Teeming time and temperature.

Although a method can be developed for calculating the heat loss to the walls of any size ladle, and this has, in fact, been applied in this study, it is not possible to calculate the overall temperature drop between tapping and teeming. This is because the heat loss from a tapping stream cannot be estimated theoretically, due to the inconsistent form of the metal stream. Furthermore, the heat effects due to ladle alloying additions cannot be calculated unless the reaction mechanism is known. Consequently, an indirect method, which was described in an earlier paper[1], had to be used. The effect of tapping stream on temperature drop was determined by the difference between the theoretical temperature drop due to heat loss to the ladle walls and the overall temperature drop determined statistically (including terms for tapping, holding and teeming times, and for three alternative ladle addition reaction mechanisms). The best correlation was taken as indicative of an acceptable ladle addition reaction mechanism.

In the following sections, the method of plant measurements, statistical correlation of plant data, and the results of the theoretical calculation of heat loss to ladle walls, together with the mechanism of ladle reactions, are briefly discussed. A graphical method of determining ladle addition heat effects is presented, and the use of these results for estimating teeming temperature from tap temperature measurements and other known variables is described.

Plant measurements

Data have been collected during normal operations of 285-ton open-hearth and 84-ton basic-oxygen furnaces, including measurements on rimmed, semi-killed, and killed steels.

All steel temperature measurements were taken with Pt-Pt 10 pct Rh thermocouples, which were calibrated against the melting point of pure iron. The recorders used were calibrated before and after each series of measurements. In taking tap temperatures of blocked open-hearth heats, measurements were made before block and also immediately before tap. In most other cases, temperatures were taken within 1 min of tap. Teeming temperatures were taken by immersing the silica sheath slowly into the teeming stream as close to the nozzle as possible. Ladle temperatures were taken with a contact chromel-alumel thermocouple to give an indication of brick temperature. Ladle additions, tapping times, holding times, and teeming times were all recorded.

Before considering an analysis of data obtained, it is necessary to examine the validity of the temperature measurements. The bath temperature measurements have been accepted as reliable—successive readings having shown a variability no greater than ±10°F. The measured teeming stream temperatures are also believed to be close to the true steel temperatures for the following reasons: The recorder traces made during stream measurements on individual ingots rose to a maximum and leveled off in a consistent manner. The change in slope of these curves was similar to measurements made in ingot tops shown in Fig. 1. The whole silica sheath, which was ½-in. shorter than the stream diameter, was immersed in the stream, and care was taken not to immerse the graphite head of the thermocouple unit. A separate observer was employed to check immersion. Smooth recorder traces were taken as a sensitive indication of a good reading.

In addition to these indications of accuracy, the consistency of the method was confirmed by the fact that a clearly-defined pattern of stream temperature showed up within any one heat using different thermocouples on succeeding measurements. This same pattern was evident whether the heats were hot or cold. Fig. 2. shows this typical pattern in the case of a heat in which the early ingots are substantially colder than those in the middle of the heat. There is also a fall off in temperature towards the end of teeming.

During this work, it was noted that temperatures below the liquidus were obtained in some heats, and these heats were often associated with ladle skulls. A ladle skull was never observed when all measurements were more than 10°F above the steel liquidus temperature. The existence of teeming stream measurements below the liquidus of the particular steel, as found in the case of some cold heats, needs some explanation. It is thought that this is indicative of liquid steel being teemed with

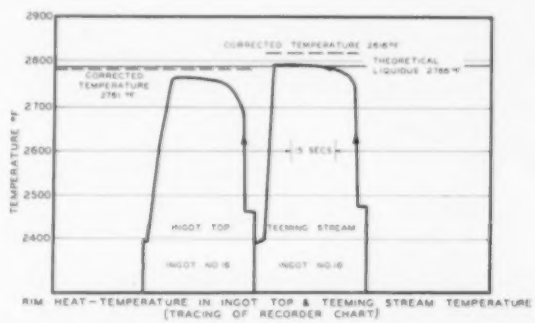


Fig. 1—Recorder traces of teeming stream and ingot top temperatures for a rimming heat.

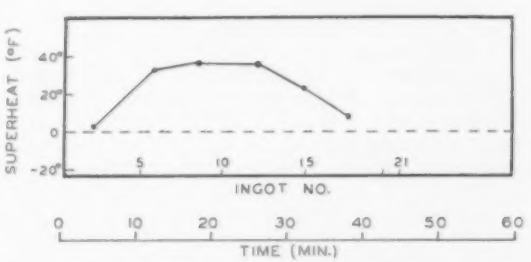


Fig. 2—Variation of super heat during teeming.

some solid included. It was found that measurements taken in the ingot top immediately after teeming gave a temperature higher than the teeming temperature, and close to the liquidus. This seems to indicate that solid material present in the stream during teeming had settled to the bottom of the ingot, leaving liquid at the liquidus temperature.

Fig. 1 also shows that the temperature in the ingot top is close to steel liquidus temperature. This is typical of both killed and rimmed ingots.

Analysis of data

Overall temperature drops between tapping and teeming were measured on 73 open-hearth heats; of these, 47 were rimmed, 8 semi-killed, and 18 killed grades. Similar measurements were made on 25 basic-oxygen heats, all of which were rimmed grades.

The hottest teeming stream temperature of the series of measurements within a heat was chosen as being representative of the average temperature of the steel in the ladle. The first few ingots teemed have a lower temperature and cannot be considered representative, probably because of temperature stratification within the ladle.

The method employed for determining the factors which affect temperature variation between furnace tapping and teeming was to equate the time intervals between furnace tapping and teeming with the measured overall temperature drop, less the temperature effect of ladle additions. This can be expressed by the following equation:

$$(\Delta T - T_a) = K + k_t t_t + k_t t_t + k_h t_h + k_p t_p \quad [1]$$

where ΔT = overall temperature drop between tapping and teeming, °F
T_a = temperature effect of ladle additions, °F
t_t, t_h, t_p = tapping, holding, and teeming times respectively; min
k_t, k_h, k_p = rate of temperature drop during tapping, holding and teeming respectively, °F per min
K = a constant.

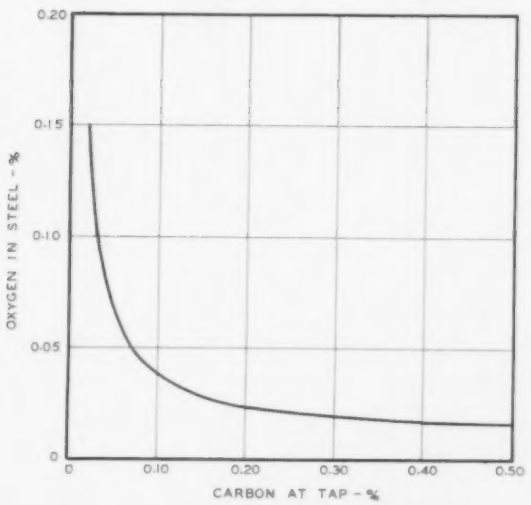


Fig. 3—Percentage of carbon at tap vs pct O in steel.

Also included in Equation [1] is a term for any temperature effect between the time that the tap temperature is taken and the furnace tapped, $k_t t_t$.

The linear expressions were chosen for simplicity and subsequent usefulness in mill calculations; this can be shown to be consistent with the theoretical treatment over the time ranges encountered.

In the case of open-hearth heats, it was found that the ladle refractory temperature did not vary outside the range of 100° to 200°F and could be neglected in the general expression. In the case of the basic-oxygen heats, the range was 100° to 1000°F and should be included. The general expression incorporating this variable is

$$(\Delta T - T_a) = K + k_t t_t + k_t t_t (T_s - T_o) + k_h t_h (T_s - T_o) + k_p t_p (T_s - T_o) \quad [2]$$

where T_s = initial steel temperature, °F
T_o = initial ladle refractory temperature, °F.

A program was set up on a digital computer to solve equations in this form for the groups of experimental data from both open-hearth and basic-oxygen furnace shops in order to give the statistically best values for the constant K and coefficients k_t, k_t, k_h, and k_p. Before solutions could be obtained, it was necessary to calculate the temperature effect due to ladle addition reactions, T_a.

Effect of ladle additions

In order to calculate the temperature effect due to ladle-addition reactions, some mechanism must be assumed. In the original study[1] three different mechanisms were postulated for each of the heats studied.

When additions are made to a ladle, alloy losses are always encountered which are due to reactions either with dissolved oxygen or with slag. These reactions produce both inclusions and carbon-monoxide gas. In either case the effect on the temperature of the steel is dubious, particularly with the slag reactions, since it is not known whether any part of the heat of reaction affects the steel temperature. Accordingly, the following three mechanisms were considered in the statistical study:

Mechanism I) Alloy losses assumed to be due to reactions with oxygen dissolved in the steel during tapping and all heat effects transferred to the steel;

Mechanism II) All alloy losses assumed to be due to reaction with iron oxide in the slag and all heat effects transferred to the steel; and

Mechanism III) All alloy losses assumed to be due to reaction with iron oxide in the slag but heat effects not transferred to the steel.

Mechanisms I and III are reasonable extremes and II has an intermediate heat effect.

A comparison of the numerical solutions of Equations [1] or [2] using the alternative values of T_a from the three assumed ladle reaction mechanisms failed to show that any one solution was clearly better than the others. However, when the independent effect of tapping stream was obtained by the difference between the theoretical temperature drop due to heat loss to the ladle walls (described in a following section) and the overall temperature drop

determined statistically, it was evident that Mechanism II gave the most acceptable result, with both open-hearth and basic-oxygen data. The statistical temperature drop was calculated for each heat by substituting the appropriate tapping, holding, and teeming times in the statistical solutions of Equation [1] or [2] together with the temperature effects of the alternative ladle-addition reactions. The preference for Mechanism II does not mean that this is the actual mechanism of ladle reactions, but only that it gives the most reasonable ladle heat effect. In subsequent discussion of ladle reactions, only Mechanism II will be considered.

Before summarizing the results of the statistical study and examining the independent effect of the tapping stream on temperature drop, a general method of calculating the temperature effect of ladle additions will be described. In this method a distinction has been made between deoxidation and alloy dissolution in the steel, together with the appropriate effect of slag reactions. To meet these conditions, the following procedure has been developed which is applicable to all types of heats, with the exception of those blocked in the furnace.

It is first necessary to know the state of oxidation of the steel in the ladle prior to alloy addition. This is assumed to be that given by the average carbon-oxygen product in the open hearth.[5] Fig. 3 shows the oxygen content in terms of the carbon at tap.

The effect of each alloying addition is then determined by using Figs. 4, 5, 6, and 7. These figures indicate the temperature effects of additions of aluminum, ferro-silicon, manganese and carbo coke in lb per ton and should be used in the order of decreasing stability of oxides of the additions. Before the correct temperature effect can be assigned to each addition, it is necessary that both the amount of alloy used in deoxidation and in alloying is known. This can be determined by comparing the amount of oxygen that could be removed by the particular alloy addition (*oxygen equivalent*) with oxygen present in the steel. If there is an excess of alloy, the difference will dissolve in the steel, whereas if there is insufficient alloy for complete deoxidation, then an oxygen residual will remain.

Figs. 4 and 5 show the equivalent oxygen for aluminum and ferro-silicon additions respectively, together with the temperature effect according to whether the addition is oxidized or appears as a residual in the steel. In the case of aluminum, it is assumed that 50 pct of the addition is lost by reaction with slag iron-oxide whether deoxidation or a residual is obtained. For ferro-silicon it is assumed that all the addition is used for deoxidizing and for dissolution in the steel, and none is lost by reaction with slag FeO. Thus, in the case of aluminum additions, the curve *aluminum oxidized* includes the following heat expressions: i) effect of heating aluminum at room temperature to steel temperature, ii) effect of reacting aluminum with dissolved oxygen, and iii) effect of 50 pct of the aluminum reacting with slag FeO. The curve *aluminum residual* includes heating the aluminum up to steel temperature and dissolution, together with the 50 pct of aluminum reacting with slag FeO. The effect of ferro-silicon additions is given in the same way and also includes the heat term for dissociating ferro-silicon and heating the iron.

As an illustration of the method, it may be seen that if 2 lb per ton of aluminum are added to a steel containing 0.2 pct O the following information can be obtained from Fig. 4:

a) 0.02 pct O in steel requires 0.82 lb per ton of aluminum for deoxidation, leaving an excess of 1.18 lb per ton for alloying;

b) The temperature effect of deoxidizing a steel containing 0.02 pct O with 0.82 lb per ton of aluminum is a 18.3°F rise;

c) The temperature effect of alloying a steel with 1.18 lb per ton of aluminum is a 9.3°F rise, and

d) The total temperature effect of adding 2 lb per ton of aluminum is 27.6°F.

The temperature effect of a ferro-silicon addition can be determined in a similar manner from Fig. 5. If a ferro-silicon addition is preceded by an aluminum addition, which completely deoxidizes the steel, then solution in the steel will occur, resulting in a silicon residual. However, if deoxidation is in-

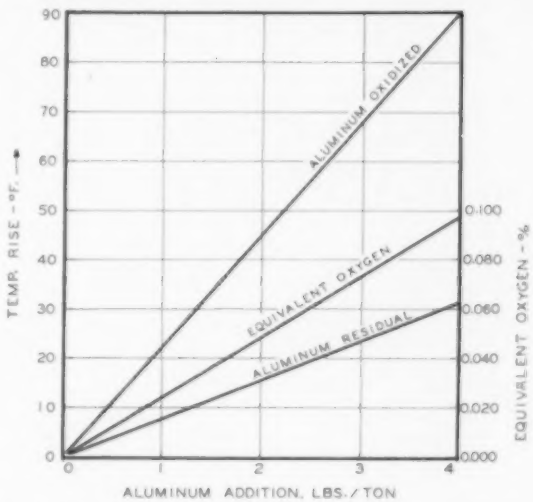


Fig. 4—Aluminum ladle addition (50 pct efficiency) vs equivalent oxygen and temperature effect.

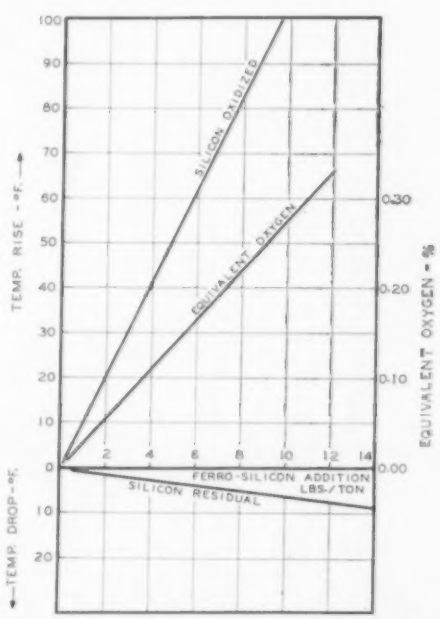


Fig. 5—Ferro-silicon (48 pct Si) ladle addition (100 pct efficiency) vs equivalent oxygen and temperature effect.

complete, the removal of the remaining oxygen can be considered in the same manner as previously described for aluminum.

The effect of manganese alloy and carbo coke additions are shown in Fig. 6 and 7 respectively. For these additions no deoxidation is considered. In Fig. 6, curves are shown for electrolytic manganese and regular manganese, including both the effect of carbon and a correction for the silicon content. For example, if an addition of 25 lb per ton of regular manganese is made to a fully deoxidized steel, then the curve shows that at 75 pct recovery the temperature effect is a drop of 35°F. The temperature effect obtained includes heating the manganese and carbon to steel temperature, together with a 25 pct loss due to reaction with slag FeO. In this case, the silicon content of the manganese will be dissolved in the steel, and the resulting temperature effect is given by the *'silicon residual'* curve. However, if the steel is not previously deoxidized, the temperature effect due to silicon deoxidation can be determined in a manner similar to that described for aluminum.

The temperature effect of carbon additions, such as carbo coke, is shown in Fig. 7 and can be determined in similar manner to the effect of manganese, although percent recoveries of carbon additions are usually lower.

Using the graphical method outlined above, it is possible to determine the temperature effect of ladle additions other than those considered in the paper. This can be done by developing curves similar to those given in Figs. 4, 5, 6, and 7, for each addition.

It should be recognized that alloying elements frequently interact to an appreciable extent, but the graphical method presented is a useful approximation.

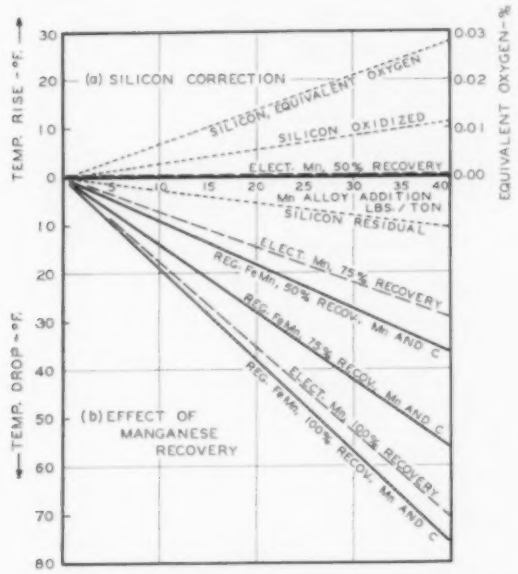

TEMP. RISE - °F.
TEMP. DROP - °F.
EQUIVALENT OXYGEN - %
(a) SILICON CORRECTION
SILICON, EQUIVALENT OXYGEN
SILICON OXIDIZED
ELECT. Mn, 50% RECOVERY
Mn ALLOY ADDITION LBS./TON
SILICON RESIDUAL
ELECT. Mn, 75% RECOVERY
REG. FeMn, 50% RECOV., Mn AND C
REG. FeMn, 75% RECOV., Mn AND C
ELECT. Mn, 100% RECOVERY
REG. FeMn, 100% RECOV., Mn AND C
(b) EFFECT OF MANGANESE RECOVERY

Fig. 6—Regular ferromanganese (75 pct Mn, 1.25 pct C, and 1.25 pct Si) and electrolytic manganese ladle additions vs temperature effect at different recovery levels together with correction for silicon reaction.

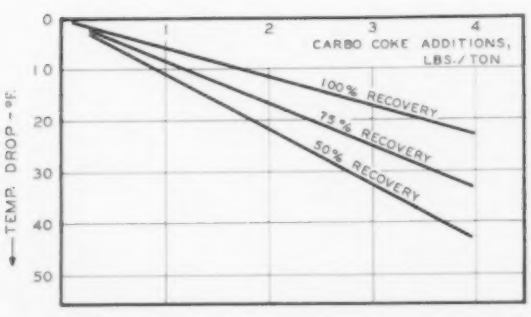


Fig. 7—Carbo coke (98.9 pct C) additions vs temperature effect at different recovery levels.

Statistical correlation of variables

The equations relating tapping, holding, and teeming times with overall temperature drop and ladle-addition temperature effect—when Mechanism II is assumed—are as follows:

Open-Hearth Data:

Number of heats = 73 (rimmed, semi-killed, and killed)

$$(\Delta T - T_o) = +42.59 - 0.24\,t_h + 2.35\,t_t + 1.64\,t_h + 0.16\,t_p \qquad [3]$$

Standard Error = 18.9°F

Basic-Oxygen data:

Number of heats = 25 (all rimmed)

$$(\Delta T - T_o) = +6.55 + 0.97\,t_h + 3.52 \times 10^{-3}\,(T_o - T_o)\,t_t + 0.93 \times 10^{-3}\,(T_o - T_o)\,t_h + 0.54 \times 10^{-3}\,(T_o - T_o)\,t_p \qquad [4]$$

Standard Error = 25.7°F

The equations obtained for the open-hearth shop show that the temperature drop between tapping and teeming can be predicted to within ± 19°F for 67 pct of all heats. This is a small error in view of the possible errors in the two temperature measurements, variations in the character of the tapping stream having the same total tapping time, and the lack of precise knowledge of ladle-addition heat effects. The equation for the basic-oxygen shop has an error of +26°F for 67 pct of the heats.

Heat losses to ladle walls

The calculation of heat loss between tapping and teeming is limited to the consideration of heat losses by conduction to the ladle brickwork during tapping, holding, and teeming periods, and by radiation from the exposed steel surface in the ladle during tapping. By the use of standard equations of heat flow, it was possible to obtain equations expressing in a general form the heat loss to the walls and bottom of a ladle of any size or shape.

Heat loss by radiation (and convection) from the exposed steel in the ladle was considered only for the period of tapping.. This is valid since, at the completion of tapping, the steel in the ladle is covered by a layer of slag which acts as an insulator.

Heat is dissipated from the slag surface principally by radiation and convection—at the expense of heat in the slag.

Calculation of heat loss from the exposed steel surface in the ladle due to convection during the tapping period was made, but it was found that this was very small compared with the other factors and could be neglected.

Temperature drops due to various heat losses discussed above were calculated using the following data:

a) Properties of ladle lining (clay fire brick):
Composition: spot analysis, 65 pct SiO_2, 27 pct Al_2O_3
Density: 125 lb per cu ft
Heat capacity: 0.20 Btu per lb °F
Thermal conductivity: 0.0081 Btu per min ft °F
Thermal diffusivity: 0.00032 sq ft per min

b) Properties of liquid steel:
Density: 449.5 lb per cu ft
Heat capacity: 0.18 Btu per lb °F

c) Temperature conditions:
Initial steel temperature: T_s = 2800°F and 2900°F
Initial ladle refractory temperature: T_o = 100°F

d) Dimensions of 285-ton ladle:

Top diam	12 ft 7 in.
Bottom diam	10 ft 5 in.
Height	13 ft 0 in.
Steel mass	600,000 lb

The results of the numerical calculations for this ladle are shown in Figs. 8 to 11.

Fig. 8 shows the temperature drop of steel as a function of total* tapping time due to conduction, radiation, and conduction and radiation combined for the 285-ton ladle. The initial ladle refractory temperature is considered constant at 100°F; the effect of heat loss due to radiation is shown for initial steel temperatures of 2800°F and 2900°F.

In Fig. 9 the temperature drop is shown as a function of holding time for various tapping times for the 285-ton ladle. The initial steel temperature is 2900°F, and the initial refractory temperature is 100°F.

Examples of temperature drop during teeming are shown in Fig. 10 for the 285-ton ladle for specific tapping and holding times. The curves shown illustrate the temperature drop associated with different total teeming times. It can be seen that, during the last stages of teeming, the rate of temperature drop becomes greater in all cases as the volume of steel in the ladle decreases, due to the increasing importance of heat loss through the ladle bottom.

It was found that a small change in either initial steel temperature or initial refractory temperature has only a minor effect on the temperature drop. However, if the difference between the steel and initial ladle temperature is appreciably different from those shown, the heat loss can be calculated by direct proportion to the change in this difference.

It will also be noted from Fig. 8 that the heat loss due to radiation is more sensitive to steel temperature than is the conduction loss.

Calculations showed that the average difference between the statistical and theoretical temperature drop for holding and teeming were 3° and 1°F, respectively.

* These curves do not indicate temperature drop during the course of tapping but only the temperature drop at completion of tapping.

In the tapping stream

The temperature drop in the tapping stream was determined by the difference between the temperature drop obtained from statistical Equations [3] and [4], and the temperature effect due to heat loss to the ladle walls as determined theoretically for each of the heats studied.

The relation between tapping time and temperature drop for the open-hearth and basic-oxygen furnaces are shown in Figs. 11 and 12. It is seen that there is less scatter in the data from the basic-oxygen furnace whereas there is only a poor correlation of temperature drop vs tapping time for the open hearth. This is consistent with observed tapping

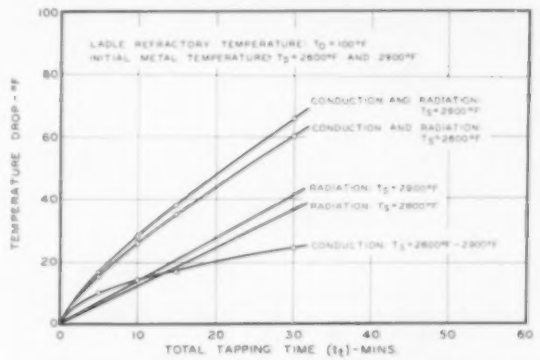

LADLE REFRACTORY TEMPERATURE: T_o = 100°F
INITIAL METAL TEMPERATURES T_s = 2800°F AND 2900°F
CONDUCTION AND RADIATION: T_s = 2900°F
CONDUCTION AND RADIATION: T_s = 2800°F
RADIATION: T_s = 2900°F
RADIATION: T_s = 2800°F
CONDUCTION: T_s = 2800°F - 2900°F
TEMPERATURE DROP - °F
TOTAL TAPPING TIME (t_t) - MINS.

Fig. 8—Theoretical temperature drop vs total tapping time for 285-ton ladle with 600,000 lb of steel.

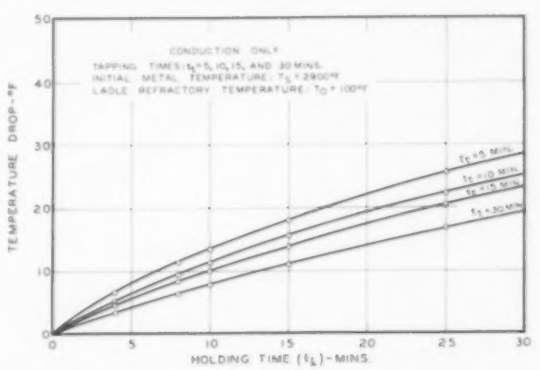

CONDUCTION ONLY
TAPPING TIMES: t_t = 5, 10, 15, AND 30 MINS.
INITIAL METAL TEMPERATURE: T_s = 2900°F
LADLE REFRACTORY TEMPERATURE: T_o = 100°F
t_t = 5 MIN.
t_t = 10 MIN.
t_t = 15 MIN.
t_t = 30 MIN.
TEMPERATURE DROP - °F
HOLDING TIME (t_h) - MINS.

Fig. 9—Theoretical temperature drop vs holding time for 285-ton ladle with 600,000 lb of steel.

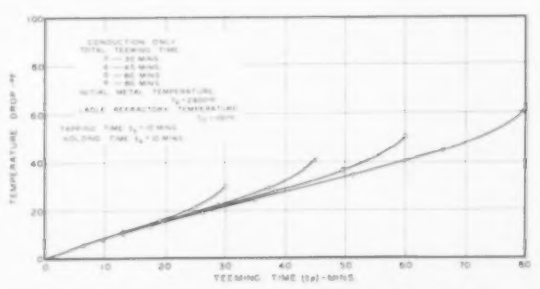


Fig. 10—Theoretical temperature drop vs teeming time for 285-ton ladle with 600,000 lb of steel.

practice. In the basic-oxygen furnace the tapping stream is relatively smooth whereas a large fixed open hearth can have widely varying tapping times and the form of the stream can be very erratic. A tilting open-hearth or electric furnace is more likely to behave similarly to a basic-oxygen furnace in this respect.

Discussion of results

The results of this work can be summarized by reference to Fig. 13, which shows the temperature changes in a typical open-hearth heat due to the factors which have been discussed. The solid line shows the individual temperature effects due to heat losses to the ladle for tapping, holding, and teeming from the theoretical curves (Figs. 8, 9, and 10). The effect of tapping stream was obtained from Fig. 9 for the appropriate tapping time. The broken line separates the temperature effects using the statistical equation, Equation [3] by inserting in it the appropriate values for t_h, t_t, t_k, and t_y. The constant K in this equation is shown as a temperature drop at zero time. In this example, the teeming temperature by the two methods differ by only 4°F and are both within 17°F of the measured teeming temperature.

It is seen that the major part of the temperature drop takes place during tapping and as a result of ladle additions. Consequently, the effect of these two variables has been considered in detail in this paper.

A determination of teeming temperature for the open-hearth or basic-oxygen shops studied can be made by solving Equations [3] or [4] for particular tapping temperature, tapping, holding, and teeming times. The effect of ladle additions can be obtained using the graphical method outlined.

Although the numerical solutions obtained in this study can only be applied to one particular open-hearth or basic-oxygen shop, the method of study is applicable to any furnace shop. In order to determine the effect of the different variables between tapping and teeming in a different shop, it is necessary to obtain statistical solutions similar to Equations [3] and [4] from the examination of a number of heats.

If it is only necessary to determine the effect of heat loss to the ladle walls, then a solution can be derived either from the curves given in this paper for the particular ladle size or from theoretical equations given in the earlier paper.[1]

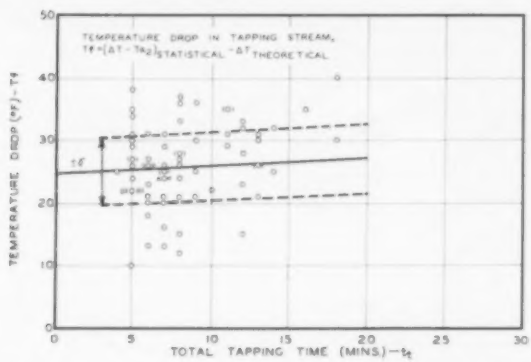


Fig. 11—Tapping stream temperature drop vs total tapping time of open-hearth furnace.

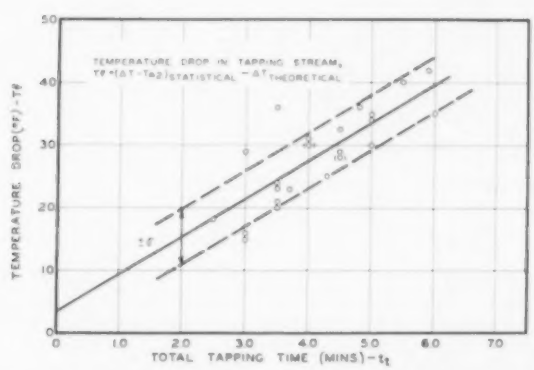


Fig. 12—Tapping stream temperature drop vs total tapping time of basic oxygen furnace.

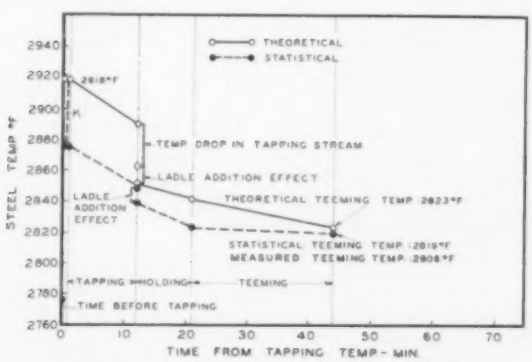


Fig. 13—Variation in steel temperature between tapping and teeming.

Conclusions

1) Statistical equations have been derived for expressing the temperature drop between tapping and teeming in the case of an open-hearth and basic-oxygen shop in terms of tapping time, ladle additions, holding and teeming times. The standard errors of the equations are comparable with experimental accuracy.

2) The effects of ladle heat losses due to conduction and radiation during tapping, holding, and teeming have been determined theoretically and have been found to be in good agreement with statistical analysis of plant measurements.

3) An estimate of the relation between temperature drop in a tapping stream and tapping time has been obtained for open-hearth and basic-oxygen furnaces by applying results of the statistical and theoretical studies.

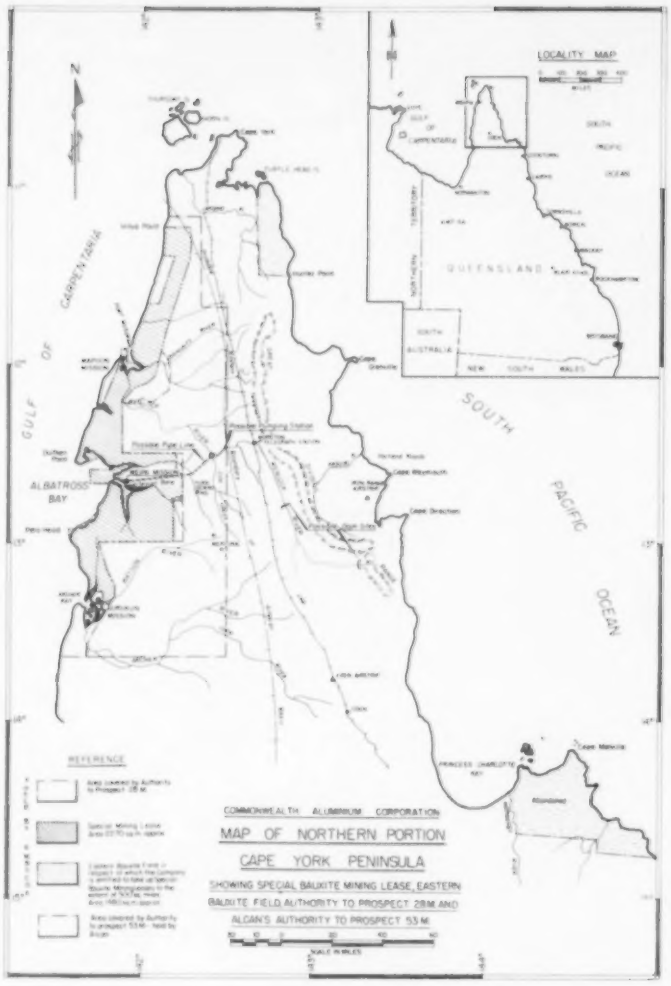
4) Heat effects of ladle additions are of similar magnitude regardless of whether they are recovered in the steel or only react with slag FeO. A general graphical method of calculating ladle addition temperature effects is presented.

5) By using the results of this work, it is possible to calculate teeming temperature from tapping temperature and other known or estimated variables.

References

[1] N. L. Samways, T. E. Dancy, K. Li, and J. Halapatz: Paper presented at the *International Symposium on the Physical Chemistry of Process Metallurgy*, Pittsburgh, Pa., April 27-May 1, 1959.
[2] *Basic Open Hearth Steelmaking*, AIME, New York 1951, p. 652.

ALUMINUM IN AUSTRALIA


LOCALITY MAP
QUEENSLAND
GULF OF CARPENTARIA
SOUTH PACIFIC OCEAN
ALBATROSS BAY
REFERENCE
COMMONWEALTH ALUMINIUM CORPORATION
MAP OF NORTHERN PORTION
CAPE YORK PENINSULA
SHOWING SPECIAL BAUXITE MINING LEASE, EASTERN BAUXITE FIELD AUTHORITY TO PROSPECT 28M AND ALCAN'S AUTHORITY TO PROSPECT 53 M.

Recently explored large-scale Australian bauxite deposits and markets for alumina produced therefrom were two topics discussed at the symposium "Aluminum in Australia". Held in July 1959 in Brisbane, Australia, the Symposium was sponsored jointly by local branches of the Australasian Institute of Mining and Metallurgy, the Australian Institute of Metals, and the Royal Australian Chemical Institute.

EXISTENCE of bauxite in Australia has been known for many years, although it is only in the last four years that discoveries in northern Australia have made the Country a potential major source of this ore. This was pointed out by G. A. Daniels and S. F. Derbyshire of the British Aluminium Co. in their paper *Bauxite Deposits of the World*, presented at the symposium, Aluminum in Australia.

The authors went on to point out that, as early as 1916, B. Dunstan announced that "laterite occurs somewhat abundantly in Queensland, and," he prophesied, "it is almost certain bauxite will be discovered in association with it in quantities attractive enough for examination."

It was not until 1955, however, that a small-scale survey was made in the Melville Bay area of northern Australia. The investigation, made by the New Guinea Resources Prospecting Co., . . . owned by the Australian government and British Aluminium . . . tested the quality of laterites, and by means of boreholes, sought to locate accumulations of aluminous laterites. Pisolitic bauxite, averaging 48 pct alumina and 3 to 4 pct silica, was discovered in quantity on Gove Peninsula, lying east of Melville Bay and west of Cape Arnhem. The survey also established that laterite deposits on the west side of Melville Bay were generally too high in silica content to be suitable for alumina production.

Cape York

That same year the east coast of Cape York in north-eastern Australia was probed by H. J. Evans, a geologist associated with Consolidated Zinc Pty., Ltd. He realized the potential of that region's pisolitic laterites—if they were of sufficiently high quality for aluminum production. Subsequent investigation by Consolidated Zinc's subsidiary, Enterprise Exploration Pty., Ltd., showed that the deposits were mainly metal-grade bauxite. Thus, a new company—Commonwealth Aluminium Corp. Pty., Ltd.—was formed by British Aluminium and Consolidated Zinc to follow up the examination and use of these bauxite ores.

This examination included surveys of both the areas at Gove on the west side of the Gulf of Carpentaria, and those on the east side of the Gulf, lying along the west coast of Cape York. As a result, the work done by the New Guinea Resources Prospecting Co. at Gove was confirmed, and areas containing metal-grade ores on the west coast of Cape

York outlined. These areas, principally designated by the cross-hatch shading on the map, consist of: The Weipa Mission Peninsula, bounded on the north by the Mission River and on the south by the Embley River . . . an area bordering on the north and west of the Mission River, extending in a northerly direction for a considerable distance . . . and the Pera Head coastal area, lying south and west of the Embley and Hey Rivers. Most of these deposits extend in from the coast for a distance of at least 20 miles.

Gulf of Carpentaria

Turning to the Gulf of Carpentaria, bauxites differ little in physical form between the east and west shores. They are typical blanket deposits overlying sand, clays, and silts. The overburden is 2 to 3 ft thick, and the bauxitic layers vary in depth from a few feet up to 30 ft. Generally, there are two quite distinct layers throughout the deposits. The markedly pisolitic upper layer contains the useful bauxite. The lower layer, consisting of irregularly-shaped ironstone and sandstone concretions, is generally too siliceous for use as metal-grade ore.

Bauxite deposits similar to those on the Gove Peninsula have also been reported in other parts of Cape York Peninsula and on Croker Island in the Northern Territory. The bauxites are good average metal-grade ore, fairly high in iron oxides, and although the predominant mineral is gibbsite, varying percentages of monohydrated alumina are present.

The tonnages of metal-grade bauxite in these combined districts is not accurately known, but the reserves are estimated at more than 3 billion tons, 2 billion of which will be metal-grade averaging 55 pct alumina, 3.5 pct reactive silica, and 1.5 pct quartz. An additional 21 million tons of metal-grade bauxite is estimated to be available throughout the country.

What about the markets?

An answer to this question was provided by J. A. Dunn, Chief Mineral Economist of Australia's Bureau of Mineral Resources, in his paper, *Australia and World Aluminium.*

"Within the space of the 1960s I can foresee no market for Australian alumina in Europe unless political problems in Africa were to inhibit or delay the development of the larger projects there. If that were to happen, there may well be some European market in the latter part of the 1960s and early 1970s, but it could well be competitive with alumina from the Caribbean and perhaps India or even communist countries."

As for North America, an alumina market on the west coast seems to be a reasonable possibility. Alumina requirements for present reduction capacities on the west coast total over 1,650,000 tons: about 500,000 tons annually at Kitimat, B. C., and 1,150,000 tons in Washington and Oregon (Alcoa, 370,000 tons; Reynolds, 270,000; Kaiser, 390,000; and Harvey, 100,000). The total will be well over 2 million tons when the final phase of the Kitimat plant is completed. Australian alumina may well prove competitive in supplying this American Pacific coast market, taking into account Panama dues on Caribbean alumina and rail freights between alumina plants at US Gulf ports and the Northwest states. My guess is that such market will be limited to those companies which may acquire linked investment in Australia alumina production—so far, Reynolds Metals Co. is a possibility. Whether Alcan, following their prospecting in the North, will establish an alumina industry here to serve the Kitimat plant remains to be seen. At the moment then, an alumina industry to supply some American Pacific coast requirement seems a likely development.

The establishment of an aluminum reduction plant in Australia, with the intention of entering the international market, is in the minds of Australians. But it is apparent that existing world capacity and projected capacity will amply take care of world requirements up to the late 1960s, and perhaps into the early 1970s. There is little possibility of Australian metal entering into world industry in a big way during that interval. Thereafter, Australia's competitive ability will depend partly on the extent to which African projects, based on African bauxites and low-cost power, can be developed. Political stability and capital availability will perhaps be the deciding factors—political stability is in Australia's favor. But, apart from African developments, by that time I would foresee the pattern of distribution of reduction plants changing, the use of raw materials and new power sources leading to more widespread self-sufficiency in aluminum production in each country.

Domestic usage

As I see it now, the obvious scope for aluminum reduction in Australia is the domestic market itself. In 1959, Australia requires about 30,000 tons—well in excess of Bell Bay's capacity of 13,000 tons which has not yet been attained. Our per-capita consumption is among the lowest of Western countries. To be comparable to western European countries and Canada, Australia's consumption should, at present, be 40,000 tons a year. To be comparable to the US, it would have to be 80,000 tons a year. Per-capita consumption is forging ahead everywhere in the world; however, aluminum marketing has not been vigorous in Australia until recently. There is great scope for further usage development, particularly in construction, transport, and consumer goods. Given the drive—on a par with the drive in America in the past 10 years—and a rate of increased consumption comparable to that expected for the world as a whole, and a rise of consumption in Australia to 100,000 tons annually by the 1970s would not be out of the question.

Plans to expand production, if only to the extent of the available alumina capacity at Bell Bay, will not close the gap with rising consumption. Whether power availability, cost, and marketing problems would permit the adequate development of Bell Bay will be clear to the group that made the survey there. The construction of an entirely new plant for additional demand may well be warranted. But whoever goes ahead with a larger reduction plant in Australia in the future must play a leading domestic role in fabricating and market development. Vigorous expansion of the market may be further implemented following vertical integration of the industry—this has been amply demonstrated by the major producers overseas.

The immediate objective could well be the initiation of such a plant, aiming to lift capacity to 100,000 tons by the 1970s. Maybe before then the next target will be clearer, and the industry will be established enough to enter the international markets, should the opportunity offer.

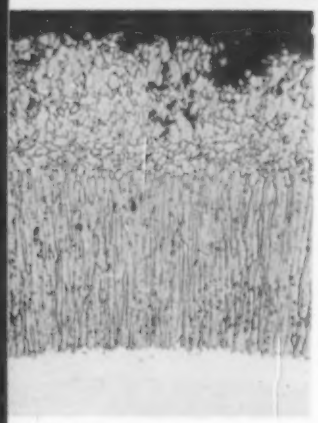


Fig. 1—Intermetallic layers on Cb wire dipped in molten Zn at 1015°F and then diffusion-annealed in air at 1600°F for 16 hr. X500, reduced to 45 pct.

COATING COLUMBIUM FOR HIGH TEMPERATURES

Frustrated by columbium's poor oxidation resistance, metallurgists are devoting considerable research effort to provide this metal with a self-healing coating. Here is one answer arrived at by the U.S. Naval Research Laboratory.

by G. Sandoz

COLUMBIUM has all the essentials for a good base-metal for the development of superior high-temperature alloys except for its poor oxidation resistance. Alloy additions confer some oxidation resistance, but only at the expense of high-temperature strength or of fabricability or both. It appears that unless and until some useful oxidation-resistant alloys are proved out, a parallel effort must be made to develop coatings for those alloys which are strong and fabricable.

In addition to providing protection against oxidation, a useful coating must also have the quality of repairing (over the temperature range to be experienced by the coated object) any cracks or flaws initially present in the coating or which might be expected to form because of mechanical or thermal strain in service. The U. S. Naval Research Laboratory has developed a type coating to meet these two requirements.

In its simplest form, this new coating consists of layers of intermetallic zinc-columbium compounds on the surface of the columbium. The intermetallics may be formed by applying zinc in any of several ways, the simplest of which is perhaps by dipping the columbium in molten zinc. Subsequently, the zinc is reacted with the columbium substrate in a diffusion-anneal in air in the general range of 1600°F, a treatment which also causes layers of zinc oxide and zinc-columbium oxide to form on the surface. Fig. 1 shows the intermetallic layers of the coated and diffused columbium.

As with most intermetallic compounds, the zinc-columbium intermediate phases are hard and brittle, and they are readily cracked either by mechanical strain or by thermal shock, but they are securely anchored to the columbium substrate and do not tend to spall, and in fact can be dislodged only with great difficulty.

Such a coating produced from unalloyed zinc and unalloyed columbium protects against influx of oxygen (as judged by microhardness traverses and bend-ductility) for several hundreds of hours at 1800°F and for a few days to a few hours in the range 2000° to 2200°F in still air.

Preliminary evaluation in hydrocarbon combustion products moving at 500 ft per sec and with metal temperature of 2000°F showed no indication of oxygen absorption or other embrittlement in tests of 5-hr duration. (Uncoated control specimens are completely converted to oxide in about 3 hr at these temperatures.) The coating thus meets the first requirement—protection against oxidation.

Perhaps the most strikingly successful aspect of the zinc-type coating is its self-healing ability. An opening in the coating to bare columbium is rapidly covered by a thin layer of oxides; zinc coming from the adjacent coating quickly re-forms the intermetallic layers. One demonstration of this capability consisted of coating and diffusing a tab of columbium ½x¾x0.063 in., and then cutting a groove ¼-in. wide through the coating and across the sample, thus exposing a bare columbium area approximately ¼x½ in.; the *flawed* sample was then placed in a furnace at 1800°F for 20 hr. After the tab was removed, it appeared as in Fig. 2. A section through the flawed zone showed a moderate increase in hardness near the flaw (original: VPN 100; final: VPN 130), suggesting a small influx of oxygen during the initial stages of healing. Fig. 3 shows the intermetallic layer re-formed at the bare area from the adjacent zinc intermetallic *reservoir*. Some of the consequences of this self-healing capability are that stress-rupture specimens are protected during extension, and *structures* do not oxidize when they are *damaged* while exposed to high temperatures.

It is intended to publish, at a later date, details of studies on the effects of third and fourth elements and other processing variables on the capabilities of this type of coating, as well as studies on the crystallography and fundamental physical metallurgy involved.

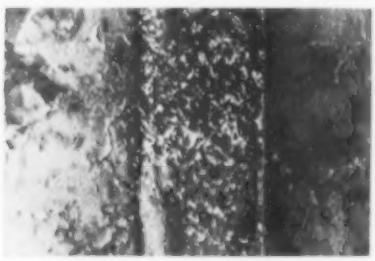


Fig. 2 (left)—A ¼ x ½-in. flaw on a coated Cb tab after reheating to 1800°F in air for 20 hr. X3.

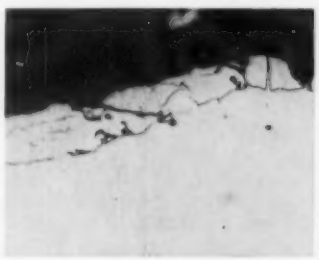


Fig. 3 (right)—The intermetallic layer reformed at the surface of the ¼ x ½-in. flaw on the coated Cb tab. X1000, reduced to 75 pct.

G. SANDOZ is with the Metallurgy div of the U.S. Naval Research Laboratory, Washington, D. C.

Reactor Fuel Reprocessing in the US

by J. A. Leary of Los Alamos Scientific Laboratory

A reactor fuel reprocessing symposium sponsored by the Atomic Energy Commission was held at Richland, Wash., on Oct. 20-21, 1959. At this meeting the AEC announced assignments for reprocessing US power reactor and experimental reactor fuels shown in Table I.

These assignments will be handled mainly by conventional aqueous-solvent extraction methods that have been utilized primarily for decontaminating and recovering both uranium and plutonium from producer reactor fuels. A cooling period of 100 to 200 days will be required to minimize radiation damage to the processing solvents. The three main processes: Redox, Purex, and Thorex, are intended for complete decontamination of the fissionable material so that fuel can be refabricated by direct handling methods.

Aqueous Reprocessing

Redox Process

The Redox process is a continuous countercurrent solvent extraction method used to recover and decontaminate uranium and plutonium from irradiated fuel.[1a] Feed solution for this process consists of nitric acid from dejacketing and dissolving operations. The acid feed solution is treated with sodium dichromate to oxidize plutonium to the hexavalent state, then fed to the first extraction column. In this column, uranium and plutonium are preferentially extracted into hexone. The hexone stream is then contacted with aqueous aluminum nitrate to scrub most of the remaining fission products out of the organic phase, and to improve extraction of uranium and plutonium. The organic effluent from the first column passes to a second column wherein it is contacted with aqueous aluminum nitrate - ferrous sulfamate solution. Hexavalent plutonium in the organic stream is reduced by ferrous sulfamate to non-extractable trivalent form. Thus, the plutonium is transferred to the aqueous stream, which is then scrubbed with fresh hexone to complete partitioning from uranium. The resulting aqueous stream contains essentially all the plutonium, while the organic stream bears virtually all the uranium. This uranium-solvent stream next passes to a third column where it is contacted with very dilute nitric acid to strip the uranium out of the hexone.

This single cycle produces three aqueous streams: 1) the bulk of the fission products from the first contactor, 2) partially decontaminated plutonium from the second contactor, and 3) partially decontaminated uranium from the third contactor. For power reactor fuels it is necessary to decontaminate these uranium and plutonium products by an additional similar hexone extraction cycle. After two cycles of extraction, the gross beta and gross gamma decontamination factors are of the order of 10^6 to 10^7 for uranium and 10^7 to 10^8 for plutonium. Material recovery is essentially quantitative.

Recent experiments indicate that it may be advantageous to replace hexone solvent with diethers such as dimethoxypentane or methoxybutoxy pentane.[2]

Purex Process

The principal difference between Redox and Purex chemistry is the use of tri-*n*-butyl phosphate (TBP) diluted with a kerosene-type solvent in place of hexone as the organic extractant, and nitric acid as the salting agent in place of aluminum nitrate.[1b]

Before extraction, the feed solution is treated to establish the plutonium in the +4 oxidation state, and to adjust acidity. In the first column both uranium and plutonium are extracted into the TBP stream, which is then scrubbed with 2*M* nitric acid. The aqueous phase, containing most of the fission products, is transferred to storage and ultimately to disposal. The organic phase, containing the fuel material, passes to a second column where both uranium and plutonium are stripped from the TBP by contacting with 0.01*M* nitric acid. This aqueous product stream is adjusted in composition, and then again contacted with TBP in a third column to re-extract both uranium and plutonium. Plutonium is partitioned from uranium by contacting with a nitric acid - ferrous sulfamate solution in a fourth column. This aqueous plutonium product stream is scrubbed with fresh TBP and put through a similar extraction cycle for further purification. The organic stream from the fourth column is stripped of uranium in a fifth contactor by treatment with 0.01 *M* nitric acid solution. This product stream also is put through another extraction cycle for additional purification.

After three complete cycles, uranium is decontaminated from gross fission product activity by a factor of 10^6, while plutonium is decontaminated by a factor of 10^7 to 10^8. Material recovery is of the order of 99.9 pct.

Laboratory-scale experiments indicate that the first-cycle decontamination can be improved by a factor of 50 by increased scrubbing of the organic phase at 70°C. A combination of this dual temperature -single cycle and ion exchange sorption achieved the same decontamination as the normal Purex process.[3a]

Ion exchange methods are being employed extensively in the final concentration and purification steps of the Purex process.[1c, 6a, 4b] The trivalent plutonium product may be sorbed on cation resins, such as Dowex-50, followed by washing and elution with 6*M* nitric acid–0.3*M* sulfamic acid. Alternatively, anion exchange resins (Dowex-1 and Permutit SK) will concentrate tetravalent plutonium in 7*M* nitric acid solution by sorbing the hexanitrato plutonium complex, followed by elution with very dilute nitric acid. Capacities of approximately 100 g plutonium per liter of resin bed are attainable at feed rates of 80 mg plutonium per sq cm per min at 50°C. Product solutions may be concentrated to a final plutonium concentration of 50 gpl.

Thorex Process

The Thorex process,[1d, 5b] developed to recover uranium-233 and thorium from irradiated thorium, is similar to Purex. However, aluminum nitrate is used as the salting agent in place of nitric acid, and thorium is partitioned from uranium by stripping with dilute acid. The uranium-233 product from the TBP solvent extraction system is further purified and concentrated by ion exchange.

Protactinium is not recovered with the uranium and plutonium products, but it is recovered in the aqueous effluent from the first extraction column. Therefore, it is necessary to store this aqueous stream for prolonged periods to allow protactinium-233 to decay to uranium-233 before processing with TBP. Recent developments indicate that prolonged storage may be avoidable by introducing a diisobutylcarbinal extraction head-end treatment to isolate protactinium before TBP extraction.[5]

Reprocessing Homogeneous Aqueous Fuel

Although most of the aqueous processing systems are designed for a high degree of decontamination, a notable exception is the reprocessing scheme for the Homogeneous Reactor Experiment (HRE) at Oak Ridge National Laboratory. In this case, where refabrication of fuel elements is not required, modest decontamination of the aqueous fuel is adequate. A continuously circulating portion of the fuel solution is passed through a series of hydroclones to remove solids. Some removal of soluble impurities is also achieved by electrodeposition on a mercury cathode.[6]

Pyrometallurgical Reprocessing

In contrast to most aqueous processes, the pyrometallurgical methods generally do not aim for high decontamination. Refabrication of the fuel would be done by remote means. However, it is anticipated that pyrometallurgical reprocessing can reduce the fuel cycle cost.

The first demonstration of a pyrometallurgical reprocessing plant will be installed with the Experimental Breeder Reactor No. 2 (EBR-2) at Idaho. This plant, to be completed in the latter part of this year, will provide reprocessing that is fully integrated with EBR-2. The reprocessing method, developed at Argonne National Laboratory (ANL)), is based on simple melt-refining of the dejacketed fuel, followed by liquid metal solution recovery of the melt refining scrap.

In addition to the EBR-2 fuel reprocessing program, a wide variety of other pyrometallurgical methods are being studied at most of the national laboratories, and by some industrial laboratories.

Melt Refining

Uranium metal fuels, containing a low concentration of plutonium, are melted on a 10-kg scale in an induction furnace to provide for removal of volatile fission products.[4c, 7] In the present concept, a zirconia crucible serves as the melt container, and as an oxide source. At 1400°C, most of the non-volatile electropositive fission products form a dross that can be separated. Zirconium, molybdenum, ruthenium, rhodium, and palladium are not removed. However, zirconium can be removed by selective carbiding. Retention of some of the fission products, notably ruthenium, is desirable for improving radiation stability of the refabricated fuel. The melt-refined product will be refabricated into rods by injection casting.

Melt-refining experiments also have been conducted with plutonium —10 atomic pct iron alloy fuel on a 1-kg scale.[8c] The results were similar to those obtained with uranium. Rare earth impurities are removed from the plutonium melt at 1400°C, while zirconium, molybdenum, and ruthenium are not.

Liquid Metal Solvents

Various reprocessing schemes are being tried with numerous molten metals such as zinc, cadmium, magnesium, aluminum, and mercury.

Process development at ANL is directed towards recovery of fissionable material from melt refining residues (principally uranium skulls), and to recovery of plutonium from uranium blankets.[6] The preferred solvent is molten cadmium, containing a few percent magnesium. Magnesium serves as a reductant for uranium oxide present in the melt refining skulls. After dissolution, the fissionable material is separated from fission products by recrystallization, or by extraction with liquid metals or salts, and then recovered by vaporization of the solvent metal.

Studies on the separation of uranium-233 thorium fuels in liquid magnesium have recently been reported.[6] When thorium—9 pct uranium alloy is immersed in liquid magnesium, thorium is dissolved selectively. Virtually all the uranium remains in an insoluble metal phase.

Table I. Reprocessing Assignments for Civilian Reactor Fuels[a]

Reactor	Fuel Element Type	Initial U Enrichment, Pct	Reprocessing Assignment
Dresden	UO_2 in Zr tubes	1.5	Hanford
Yankee	UO_2 in SS tubes	2.6	
Shippingport (blanket only)	UO_2 in Zr tubes	natural	
Northern States	UO_2 in Al-Ni plates	1.8	
Piqua	U clad with Al-Ni	1.8	
Shippingport (core only)	U-Zr alloy clad with Zr	90	Idaho
OMRE	U-SS mixture clad with SS	90	
SM-1 (ex APPR-1)	U-SS mixture clad with SS	90	
Vallecitos	U-SS mixture clad with SS	90	
SL-1 (ex Argonne Low Power Reactor)	U-Al-Ni in Al-Ni plates	90	
Research and test reactors domestic and foreign	A-Al alloys	90	
Fermi Fast Breeder (blanket only)	U-Mo alloy in SS tubes	depleted	Oak Ridge
Hallam	U-Mo alloy in SS tubes	3.5	
N.S. Savannah	UO_2 in SS tubes	4.1	
Indian Point	ThO_2-UO_2 in SS tubes	90	
Elk River	ThO_2-UO_2 in SS tubes	90	
Borax-4	ThO_2-UO_2 in tubed Al plates	90	
EBWR	U-Zr alloy in Zr plates	1.5	
SRE	U rods in SS tubes	3.5	
Research reactors, foreign	U-Al alloy	20	
Fermi Fast Breeder (core only)	U-Mo alloy clad with Zr	27	Savannah River

[a] Reprinted from *Nucleonics*, December 1959, p. 24; Copyright 1959, McGraw-Hill Publishing Co. Inc.

Several processing methods employing mercury as solvent have been reported.[4d, s] The fissionable material is first dissolved in hot mercury, followed by filtration and recrystallization. Soluble alkaline earths and rare earths are dissolved with the fissionable material and tend to coprecipitate. However, they may be separated by selective oxidation. The recrystallized product can be decomposed by vacuum distillation of the mercury.

The feasibility of an aluminum solvent system for uranium fuel processing is being investigated by the Dow Chemical Co. at Midland, Mich.[s] After dissolution in molten aluminum, uranium is precipitated as UAl_3 by addition of magnesium. The precipitate is dissociated by washing with zinc, and uranium is recovered by distillation of the zinc.

In addition to processes based on dissolution of the fuel in liquid metal solvents, the application of immiscible liquid metal extractants is also being evaluated at the Ames Laboratory of Iowa State College. The distribution of fissionable and fission product metals between uranium-chromium melts and molten magnesium-silver has been determined.[10]

Fused Salt Processes

Fused salt systems can be employed in numerous ways to reprocess irradiated fuels. The most simple type of process is based on selective oxidation of the electropositive fission products by contacting an oxidizing salt phase with the molten fuel. An alternative method is to selectively oxidize the electropositive fission products and all of the fissionable material, followed by selective reduction of the fissionable constituent from the salt phase.

Removal of electropositive fission products from liquid bismuth-uranium fuel proposed for the LMFR can be achieved by contacting the fuel with magnesium chloride or bismuth chloride dissolved in a ternary salt eutectic solvent.[11] Similarly, equilibration between molten plutonium-iron alloy and molten salts that contained magnesium chloride effected good removal of the electropositive elements.[8e]

Dissolution of plutonium-iron alloy containing fission product elements in molten zinc chloride - sodium chloride produces a new salt phase that contains all of the plutonium and electropositive elements.[4d] Less electropositive elements are retained in the liquid zinc metal by-product phase. The plutonium can be reduced selectively from the new salt phase. Similar studies are being conducted with uranium-thorium fuels.[10]

Fused-salt reprocessing methods are being considered for application on the Plutonium Recycle Test Reactor.[8d] Plutonium may be recovered from oxide fuel by dissolving in molten aluminum chloride - potassium chloride, followed by reduction. Plutonium remains predominantly in the salt phase, while uranium concentrates in the molten aluminum. Plutonium-aluminum alloy fuel can be replenished by adding plutonium as plutonium dioxide to molten cryolite, followed by reduction with excess aluminum to form the desired plutonium-aluminum alloy.

Electrolytic Processes

Electrorefining at temperatures of 600 to 1000°C offers considerable promise as a reprocessing method for both uranium and plutonium fuels. Excellent purifications have been achieved using impure fissionable material as the anode and molten salt as the electrolyte. When a refractory metal is used as the cathode, the purified uranium or plutonium is collected in elemental form. Alloying of the cathode deposit has been accomplished *in situ* by employing a cathode made of the desired alloying agent. Manganese has been used to alloy uranium,[12] and iron cathodes have been used to form plutonium-iron alloys.[4d] By properly adjusting cell conditions it is possible to collect these low-melting alloy products continuously.

Oxidation-Reduction Cycling of Oxide Fuel

Reprocessing of uranium dioxide by alternate oxidation-reduction cycles is being studied at Atomics International.[8e, 8f] Oxidation of the urania to U_3O_8 by heating in air and oxygen serves to pulverize the material. This enables direct removal from zirconium cladding. The pulverized material is reduced with hydrogen to reconstitute the dioxide fuel, after which the cycle is repeated several times. Most of the cerium, ruthenium, tellurium, iodine, and probably rare gases are removed in this process.

A similar approach is being tried with uranium carbide. The carbide is converted to uranium dioxide, which is then reverted to uranium carbide by reaction with carbon at temperatures of about 2000°C.

Volatility Processing

Processes based on the volatility of uranium hexafluoride and plutonium hexafluoride are being studied at ORNL[13] and ANL[5e]. Uranium-zirconium alloy fuels are dissolved in molten fluoride salts by the addition of hydrogen fluoride to the molten salt phase. After volatile zirconium fluoride is removed, the salt is treated with fluorine to form uranium hexafluoride, which is then recovered and purified by an absorption-desorption cycle or by distillation. Uranium-plutonium fuels may be treated in a similar manner. Reduction of the hexafluoride to metal can be accomplished by standard methods.

Fluoride volatility processing has been used for recovery and decontamination of uranium from the ARE molten salt fuel.[14]

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NEWS OF YOUR PROFESSION

REFRACTORY METALS PROGRAM

The program for the May Refractory Metals and Alloys symposium, at this writing, is listed below. The symposium will meet at the McGregor Center on the Wayne State University campus in Detroit on May 25-26. The Institute of Metals Division, in cooperation with the Detroit section, AIME, is sponsoring the event.

WEDNESDAY, MAY 25

General Metallurgy

9:35 am—*Phase Equilibria and Relationships in Refractory Alloys*, W. R. Rostoker, Armour Research Foundation.

9:55 am—*Mechanical Behavior of Refractory Metals and Alloys*, J. H. Bechtold, E. Wessel, and L. L. France, Westinghouse Electric Corp.

10:45 am—Break

11:00 am—*Strengthening of Refractory Alloys*, W. H. Chang, General Electric Co.

11:50 am—*Oxidation Behavior of Refractory Metals and Alloys*, J. W. Semmel, Jr., General Electric Co.

12:30 pm—Luncheon, topic: *Survey of European Developments in Refractory Metals* (speaker to be announced).

Refractory Metals and Alloys

2:00 pm—*Chromium and Chromium-Base Alloys*, N. J. Grant, MIT.

2:40 pm—*Present and Future of Columbium Alloys*, R. G. Frank, General Electric Co.

3:20 pm—Break

3:30 pm—*Physical Metallurgy of Columbium and its Alloys*, S. J. Anders, Du Pont Experimental Station.

4:10 pm—*Molybdenum and Its Alloys*, M. Semchyshen, Climax Molybdenum Co. of Michigan.

THURSDAY, MAY 26

Refractory Metals and Alloys

9:00 am—*Tantalum and Tantalum-Base Alloys*, A. B. Michael, Fansteel Metallurgical Corp.

9:50 am—*Tungsten and Tungsten-Base Alloys*, R. Atkinson and R. C. Koo, Westinghouse Electric Corp.

10:30 am—*Renium and Platinum-Group Refractory Metals*, R. I. Jaffee, D. J. Maykuth, and R. W. Douglass, Battelle Memorial Institute.

11:10 am—Break

General Engineering

11:20 am—*High Temperature* (< 2000°F) *Mechanical Properties*, Robert W. Hall, Paul Sikora, and G.M. Ault, National Aeronautics and Space Administration.

12:00 m—Luncheon, topic: *Refractory Metals Activities in Agard*, N. E. Promisel, Dept. of the Navy.

1:50 pm—*Fabrication and Processing of Refractory Metals*, C. P. Mueller, Universal-Cyclops Steel Corp.

2:30 pm—*Protective Coatings for Refractory Alloys*, E. D. Sayre, L. Luft, and J. W. Graham, General Electric Co.

3:15 pm—Panel Discussion: *Comparative Status of Refractory Metals for Engineering Applications*. Participants: E. Czarnecki, Boeing Aircraft Co.; G.M. Ault, NASA; R. A. Perkins, Aerojet-General Corp.; A. V. Levy, Huges Tool Co.; and L. M. Raring, Pratt & Whitney, div of United Aircraft Co.

Detroit Skyline at Night

Fall Meeting Abstracts

June 29th is the deadline for submission of abstracts to be considered for presentation in IMD-sponsored sessions at the 1960 Fall Meeting of The Metallurgical Society.

In order to be considered for inclusion in the program, each submission must include:

1) A 200-300 word abstract typed double-space on one side of the paper only. (No photographs, figures, tables, or diagrams, please.)

2) Complete mailing address of *each* author on a separate sheet, together with title of paper being submitted.

3) Acknowledgements of research sponsorship, *where applicable*.

All required information and abstracts should be submitted in 3 copies to:
The Metallurgical Society of AIME, IMD Program Committee, 29 W. 39th St., New York 18, N. Y.

NEW ENGLAND REGIONAL MAY 26-27

The preliminary program for the 14th New England Regional Conference, scheduled for May 26-27 in the Bay State Room, Hotel Statler-Hilton, Boston, appears below. Metalworking Tomorrow will be the theme of the Conference, sponsored by the Boston, Hudson-Mohawk, and Connecticut sections of AIME.

THURSDAY, MAY 26

8:00 am—Registration
9:00 am—12:00 noon

High Energy Rate Forming

Chairmen: L. R. Frazier, Metal Hydrides Inc., Beverly, Mass.; and L. P. Kaufman, Manufacturing Labs Inc., Cambridge, Mass.
Theory of High-Speed Forming, R. S. Davis, A. D. Little Co.
Explosive Forming, J. S. Rinehart, Colorado School of Mines.
Practical Aspects of Explosive Forming, speaker to be announced.
Applications of High Energy Rates to Manufacturing Techniques, E. W. Feddersen, Fort Worth div, Convair.
Panel Discussion: C. O. Williams, Olin Mathieson Chemical Corp., and others, including authors listed above.
12:00 noon—Luncheon (included with registration fee).
Speaker: William Congleton, American Research and Development Corp.
Subject: *New Businesses Based on Technological Advances.*
Toastmaster: T. B. King, Massachusetts Institute of Technology.
2:15 pm-5:00 pm

Special Metalworking Processes

Chairmen: R. S. Bray, Chase Brass and Copper Co., and J. B. Wagner, Yale University.
Looking Ahead in Forging, H. B. Goodwin, Battelle Memorial Institute.
Fabricating Processes to Obtain Special Properties, Eric B. Kula, Watertown Arsenal Laboratory.
Shear Spinning, Serope Kalpakcioglu, Cincinnati Milling Machine Co.
Future Metal Processing Problems, D. W. Lillie, General Electric Co., Schenectady, N. Y.
Panel Discussion: W. H. Sharp, United Aircraft Corp., and others, including authors listed above.
5:15 pm—Social Hour (included with registration fee).

FRIDAY, MAY 27

9:00 am—12:15 pm

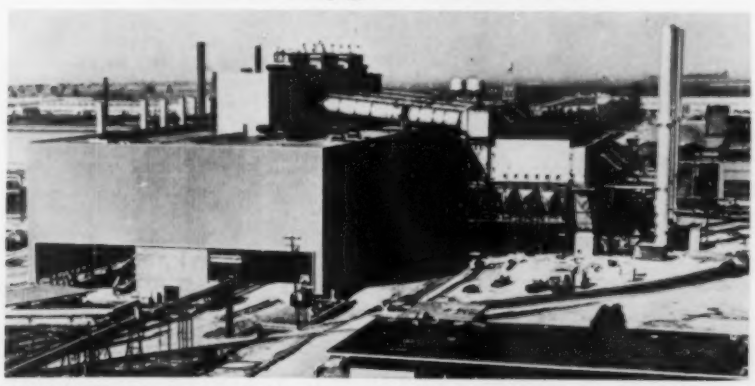
Extrusion

Chairmen: R. P. Carreker, General Electric Co., Schenectady, and E. Nippes, Rensselaer Polytechnic Institute.
Theory of Extrusion and Calculations, W. A. Backofen, Massachusetts Institute of Technology.
Composite Extrusions, A. R. Kaufmann, Nuclear Metals Inc.
Extrusion of Metal Powders, Eric Gregory, Air Reduction Co.
Precision Cold Extrusion, R. A. Quadt, Bridgeport Brass Co.
Panel Discussion: J. R. Hughes, General Electric, Schenectady; R. M. Treco, Olin Mathieson, and others, including authors listed above.
1:30 pm—Buses leave for tour of Avco Research and Development Division Laboratory, Wilmington, Mass.

General Information

Registration—Registration, including cost of May 26th lunch and social hour is $10 for AIME members; $15 for non-members. Advance registration may be made by sending check to *F. S. Chudy, Olin Mathieson Chemical Corp., New Haven, Conn.* Registrants should make their own hotel reservations.

Fontana Oxygen Steel Works



PLANT VISIT—The Fontana, Calif., oxygen steelmaking facilities of Kaiser Steel Corp. will be visited by members of the AIME's Acid Converter and Basic Oxygen Steel Committee during its Annual Meeting. The Ambassador Hotel in Los Angeles will be host to this meeting, plus the Southwest Metals and Minerals Conference, Western section, NOHC, meeting, and a Manned Space Stations Symposium Apr. 20-23.

CLIFFORD J. HICKS

New AIME Assistant Secretary Appointed

Clifford J. Hicks was recently added to the AIME staff as Assistant Secretary and Western Field Secretary. He succeeds the late Roy E. O'Brien to the post, and will maintain office in Salt Lake City.

No stranger to AIME, Mr. Hicks served as secretary of the Montana section for seven years. He is currently on the Section's executive committee.

Before joining AIME full-time, Mr. Hicks was senior geologist of The Anaconda Co.'s Kelley Mine in Butte, Mont. He has spent the majority of his professional career with Anaconda, becoming associated with the company in 1947 as a junior mining engineer. Born in Wisconsin, Mr. Hicks received a B.S. in geology from the University of Wisconsin.

Space Age Meetings in LA April 21-23

Sessions on Beryllium Metallurgy and Materials for Space Vehicles will be included in the AIME Southwest Metals and Minerals Conference in Los Angeles Apr. 21-23. The meeting will be headquartered in the Ambassador Hotel there.

Three other related meetings will be housed there at the same time—the Acid Converter and Basic Oxygen Steel Committee's Annual Meeting . . . Western section, NOHC, meeting . . . and a Manned Space Station Symposium, sponsored by the National Aeronautics and Space Administration and others.

Registration fee for the Southwest Metals and Minerals Conference is $5 for both members and non-members. Send checks to *C. W. Six, Treasurer, Southwest Metals and Minerals Conference, 1200 Pacific Mutual Bldg., 523 W. Sixth St., Los Angeles 14, Calif.* Hotel reservations should be made through the *Reservation Manager, Ambassador Hotel, 3400 Wilshire Blvd., Los Angeles 5, Calif.*

OFFICERS OF THE METALLURGICAL SOCIETY

(Biographies and pictures of the Society President and Division Chairmen appeared in the February issue).

JOHN CHIPMAN

John Chipman, head of the Dept. of Metallurgy at Massachusetts Institute of Technology, becomes Past-President of The Metallurgical Society for 1960. His previous offices have included Chairman of the Iron and Steel Division, AIME, in 1957, and President of the American Society for Metals, 1952. For many years he has served as a member of the AIME Physical Chemistry of Steelmaking committee and the Publications committee. Following receipt of a Ph.D. in physical chemistry from the University of California in 1926, he joined the Georgia School of Technology as asst. professor of chemistry. His next stop was the University of Michigan, and it was here that he began application of physical chemistry to metallurgical problems. His interest in the chemistry of liquid iron and steel has led to considerable publication, principally in TRANSACTIONS OF THE METALLURGICAL SOCIETY.

In 1934, Dr. Chipman became Associate Director of the Research Laboratories of the American Rolling Mill Co. (now Armco Steel Corp.) He moved to MIT as professor of metallurgy in 1937, becoming head of the Department in 1946. Dr. Chipman's research has been recognized in a number of awards, including the *Robert W. Hunt Medal* (AIME), the Henry M. Howe Medal (ASM), the Bessemer Gold Medal (Iron and Steel Institute), the Losana Gold Medal (Italian Metallurgical Association), and the Brinell Gold Medal (Swedish Academy of Engineering Sciences). In 1949, he delivered the Howe Memorial Lecture of the AIME, speaking on *What is Metallurgy?*

* * *

Vice President and President-Elect of The Metallurgical Society for 1960 is John S. Smart, Jr. He automatically becomes President of the Society in 1961. Mr. Smart is also a Director on the AIME Board of Directors.

Professionally, Mr. Smart is general sales manager at the American Smelting & Refining Co. Leading up to this post, were duties at the Ford Motor Co. and Detroit Lubricator Co.; he joined ASARCO as a research metallurgist in 1936. His major interests then were in copper metallurgy and continuous casting; he was the innovator of several now-patented continuous casting processes. He is also internationally known as an authority on the properties and treatment of copper. His major research interest now is in the preparation and properties of high-purity copper . . . effects of impurity additions . . . and the development of continuous casting processes for bronzes and commercial types of copper.

Steps on the administrative ladder between research engineer and sales manager have been: supt. of copper development, asst. to the vice president and director of research, and asst. director of research.

Mr. Smart's AIME activity includes a one-year term as a Director (1955). In 1954 he was chairman of the Rossiter W. Raymond Award Committee. He was himself the recipient of the IMD Award in 1948, now called the *Mathewson Gold Medal*. In 1955, he was the Annual Lecturer of the Australian Institute of Metals.

J. S. SMART, JR.

T. D. JONES

Thomas Delbert (T. D.) Jones is in his third year as Treasurer of The Metallurgical Society. A member of AIME since 1921, he has taken a leading role in the Extractive Metallurgy Division's activities, serving as chairman of that group in 1952. He has also been on the EMD Executive Committee, the all-Institute Admissions Committee, and the National Steering Committee. In 1959, he was Treasurer of the EMD, and a member of the AIME Admissions, Finance, and Fiscal Policy and Future Developments committees, in addition to being Treasurer of The Metallurgical Society.

Following graduation from the University of Wisconsin, he joined the American Smelting & Refining Co. as a chemist. He is still with them after 37 years, now holding the title of Chief Lead Refinery Metallurgist.

DIRECTORS

* Year of expiration of term.

EMD

Ronald R. McNaughton

Mr. McNaughton ('61)*, is serving a term as President-Elect of the AIME coincident with his last year as a Director of The Metallurgical Society from the Extractive Metallurgy Division. Mr. McNaughton will become AIME President in 1961.

He hails from Canada, working as manager of the Metallurgical div. of the Consolidated Mining & Smelting Co. of Canada, Ltd. Mr. McNaughton has been at Consolidated Mining since graduation from McGill University 35 years ago. He rose from asst. foreman in the smelting dept. to his present position via administrative appointments. Active in AIME activities for many years, Mr. McNaughton served as Chairman of the EMD in 1953. He was a Director of AIME that same year, and the year following.

John D. Sullivan

Mr. Sullivan ('62)* is technical director of Battelle Memorial Institute. One of the Extractive Metallurgy Division's founders, he was its first Chairman (1948-1950). But his activity in AIME dates from his joining the Institute in 1930. Mr. Sullivan is a former Chairman of the Douglas Award Committee, and has been a member of the EMD's Executive Committee and Publications Committee. He has also served on the IMD Executive Committee. The Battelle Director is himself the author of more than 100 papers in metallurgy, chemistry, and ceramics.

IMD

William J. Harris, Jr.

Dr. Harris, ('61)* Executive Director of the Materials Advisory Board, National Academy of Sciences-National Research Council, (NAS-NRC) is filling the term of office vacated when J. S. Smart, Jr., took the post of Vice President. The office is not new to him, however, having been an IMD Director in 1957-1958 and Chairman of the IMD in 1958. Currently, he is on the AIME Nominating Committee, and the IMD Budget and Nominating committees.

Dr. Harris came to the NAS-NRC in 1957, previously serving as Assistant to the Director, Battelle Memorial Institute. The Chairman of numerous Materials Advisory Board panels, Dr. Harris has been the recipient of many awards; among them is the AIME *Mathewson Gold Medal* (1950) in collaboration with Morris Cohen, MIT. Dr. Harris received his

John H. Hollomon

Dr. Hollomon ('62)* has just been named General Manager of the General Engineering laboratories, Schenectady, N. Y. A member of the AIME since 1944, his many honors are too numerous for space requirements. Most recently, however, was his election as a Fellow of the American Academy of Arts and Sciences. In 1954, he was chosen one of the Country's 10 leading young scientists in industry, by the US National Junior Chamber of Commerce.

An active AIME member, he was a member of The Metallurgical Society's Committee on Metallurgical Profession and Publications Committee during 1959.

ISD

Harold B. Emerick

Mr. Emerick ('61)* has been an AIME member since 1943, serving actively during the years. He was Chairman of the Iron and Steel Division (1957) and Past-Chairman (1958) Professionally, he is director of technical services for Jones & Laughlin Steel Corp. He joined J & L as a metallurgical investigator in 1935, while still attending Carnegie Institute of Technology. In 1942 he co-authored *The F. B. McKune Memorial Award* winning paper on open-hearth practice. Mr. Emerick is the author of **Basic Open Hearth Steelmaking**, published by the AIME in 1951. He is also a member of the American Society for Metals and the American Iron and Steel Institute.

Ralph W. Farley

Mr. Farley ('62)* has served on the ISD Electric Furnace Conference Committee and the Physical Chemistry of Steelmaking Committee, in addition to his duties as an ISD Director. With the Republic Steel Corp. since 1935, Mr. Farley is now director of process development for the Chicago district. He received a B.S. in chemical engineering from the University of Michigan in 1932. And prior to joining Republic, he worked as a plating foreman and consultant with the Diamond Silver Co. A member of the AIME since 1946, Mr. Farley is also a member of the ASM and API.

(OVER)

EMD

A. W. Schlechten

Dr. Schlechten ('63)* has been professor of metallurgical engineering and Chairman of the department, Missouri School of Mines and Metallurgy, since 1946. On receiving his Ph.D. from the Massachusetts Institute of Technology in 1940, Dr. Schlechten joined the University of Minnesota faculty. He served there from 1940 to 1942, then moved to Oregon State College from 1942 to 1944. From 1944 to 1946 he was a metallurgist for the US Bureau of Mines, working with Dr. W. J. Kroll in development of a process for production of ductile zirconium.

Past and present member of many AIME, Society, and EMD committees, Dr. Schlechten has been active in Institute activities since his 1934 joining. He is also a past chairman of the EMD, as well as the St. Louis section of AIME. In 1953, Dr. Schlechten was given the American Society for Metals' $2000 Teaching Award for his ability as a teacher of metallurgy. Counted among his honors is the position of Editorial Advisor to the Encyclopedia Britannica on all mining and metallurgy subjects.

ASM Southwestern Meeting in Dallas

The American Society for Metals' 2nd Southwestern Metal Congress will be held May 9-13 at the Sheraton-Dallas Hotel. Technical session themes are as follows: Steels for High Load Applications . . . New Frontiers in Welding and Brazing . . . Composite Materials for High Temperature Applications . . . New Metal Forming Techniques . . . Heat Treatment of Problem Materials . . . Failure Analysis . . . and Testing at Temperatures Over 2000° F. Education displays will also play a part in the meeting, on exhibit in Texas State Fair Park.

IMD

Karl L. Fetters

Dr. Fetters ('63)* is vice president of research and development, The Youngstown Sheet and Tube Co. Dr. Fetters was the 1958 Chairman of the Iron and Steel Division. He was also Chairman of the Division's Nominating Committee in 1959. A member of the AIME since 1937, he was a metallurgical assistant with the National Tube Co. from 1933 to 1936 and open-hearth metallurgist, Youngstown Sheet and Tube Co., 1936-1938. Next came a return to academia, resulting in a Ph.D. from the Massachusetts Institute of Technology in 1940. He went back to Youngstown Sheet and Tube for one year, and then came a two-year stint as assistant professor of metallurgy, Carnegie Institute of Technology. He rejoined Youngstown Sheet in 1943 and has continued the association. Among his awards is included the American Iron and Steel Institute's Medal (1948) for co-authoring a paper on *The Mineralogy of Basic Open Hearth Slags.*

Spokesmen and Subjects Named for Powder Metallurgy Conference

Paul Swarzkopf, Honorary Chairman of the International Powder Metallurgy Conference meeting at the Biltmore Hotel in New York City June 13-17, will deliver the Conference's keynote address. *Half a Century of Modern Powder Metallurgy* will be the subject of Dr. Schwarzkopf's talk. Dr. Schwarzkopf is President of Metallwerk Plansee, GmbH, Reutte, Austria.

Later on that same Monday, June 13th, Kempton H. Roll, Executive Secretary, Metal Powder Industries Federation, will be the spokesman at the 12:15 pm Welcoming Luncheon in the Fountain Court. His subject will be *Power Metallurgy and the Metal Powder Industry in the US and Canada Today.*

Altogether, the Conference will include three days of symposia and two days of plant trips. The complete Conference program will appear in the May issue.

ISD

Jack H. Scaff

Mr. Scaff ('63)* has been a member of the Research Staff of Bell Telephone Laboratories for 30 years. There he has been responsible for research and development in the field of magnetic materials, semiconductors, and other communication materials responsive to metallurgical control. He and his associates pioneered in silicon metallurgy prior to World War II, resulting in the first P/N junctions in silicon. The group had a major part in the development of the first detectors for microwave radar receivers during the war and contributed significantly to the discovery, development, and manufacture of transistors, as well as germanium and silicon diodes. The author of a number of technical papers in this field, Mr. Scaff also co-authored one of Bell Laboratories' books, **Transistor Technology.**

He has also been awarded a number of patents relating to semiconductor technology.

Active in professional affairs, he has served on the Panel on Non-Magnetic Steels and the Panel on Magnetic Materials, Materials Advisory Board, National Academy of Sciences. Mr. Scaff has been Chairman of the Program and Membership Committees, AIME, and a member of the Executive Committee. He became Chairman of the Institute of Metals Division and Director of AIME in 1954, and Chairman of the Metals Branch Council, forerunner of The Metallurgical Society, in 1955.

Materials Conference Hosts Metals Sessions

Sessions on metals and fabrication are included in the American Society of Mechanical Engineers Design Engineering Conference at the Coliseum in New York, May 23-26. A Design Engineering Show featuring the products of some 400 companies will be held simultaneously with the Conference. Those who want information about the Conference, Show, hotel reservations, or rapid registration cards should write *Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.*

STUDENT NEWS

Carnegie Institute of Technology

The Student Society of Metals, AIME chapter on the Carnegie Tech campus, heard Dennis Ryan, asst. director of the Placement Bureau at the school, during its Feb. 22nd meeting. A total of 48 members listened to a description of the correct procedure for arranging and having interviews. Mr. Ryan also pointed out things to do and avoid doing. He also gave hints to underclassmen seeking summer jobs. Following the question period, refreshments were served.

At an earlier meeting on Feb. 16th the student chapter's 1960 officers were elected. They include: Mike Georgelis, president; Fred Loepp, vice president; Hershell Tkatch, treasurer; Harvey Stein, secretary; and Denis Creazzi, social chairman.

Yale University

The AIME chapter at Yale, the Yale Metallurgical Society, has the following officers whose terms expire in June: H. Robert Baumgartner, president; George A. Keyworth, secretary-treasurer; and Martin Seltzer, graduate student adviser. The chapter's current faculty adviser is J. Bruce Wagner, Jr. Malcolm F. Burr is industrial counselor.

Northwestern University

On Feb. 6th, a party was held at the home of the Northwestern student chapter adviser, Morris E. Fine. Honored guests were Johannes Weertman and Jerome B. Cohen, two new additions to the school's Department of Metallurgy and Materials Science. A total of 50 students, faculty members, and wives enjoyed an evening filled with pizza and wine.

Officers of Northwestern University's Metals Club with terms expiring in June, are: Robert G. Wolfson, president and program chairman; and Lyle H. Schwartz, vice president and secretary-treasurer.

Case Institute of Technology

The membership of Case Metallurgy Society has increased from 33 to 52 since last fall—one of the largest memberships it has ever had.

G. Willy Form, faculty adviser, attributes the increase to careful planning of each meeting and appropriate advertising. "The idea of having an executive committee meeting every other Tuesday, which we have implemented over a year now, pays off in planning of programs, as well as direction of the Society's affairs. . . ." says Dr. Form.

A total of eight formal meetings is planned for this semester, including three speakers, three movies, a panel discussion, and a business meeting. In addition, two stag parties are being organized in fraternity houses, and the Society's Annual Dinner will be held.

The Feb. 9th meeting of the Case Metallurgy Society featured a movie called *Cobalt in Katanga*, produced by the Battelle Memorial Institute.

During the business portion of the meeting Dr. Form announced that the eighth meeting of the semester would highlight a panel discussion by several seniors in the Society. Job interviews will be the subject of discussion.

Kansas University

Officers of the Kansas University AIME student chapter, with terms expiring in June, are: Charles F. Gibbon, president; William Gurwell, secretary; and Kenneth McDowell, treasurer; Galen Hodge is the Engineering Council representative.

Lafayette College

John Markle Society, student metallurgy group at Lafayette College, was visited by Daniel Eppelsheimer on Feb. 19th. Dr. Epplesheimer, professor of physical metallurgy at Missouri School of Mines and Metallurgy, addressed a group of 85, made up of Markle Society members, ASM students from the Lehigh Valley chapter, students from nearby Lehigh University, and guests. Leon J. McGeady, head of the Department of Metallurgical Engineering, Lafayette College, introduced the speaker. Dr. Eppelsheimer spoke on *Materials Problems in Nuclear Engineering*. The speech was illustrated by slides and a short film. Refreshments followed the talk.

University of Pennsylvania

Reactivation of the AIME student chapter on the Pennsylvania campus is underway. Plans were formulated for a joint meeting with Drexel Institute of Technology's ASM group on March 15th. The Pennsylvania chapter will reciprocate by playing host in May. The AIME local section in Philadelphia is helping in this student chapter revitalization by offering to cover the expenses of their meeting.

On Feb. 25th, 16 students from the University of Pennsylvania took up the Philadelphia section's standing offer to visit one of its monthly meetings. They heard Dr. Wolfe of Bell Labs speak on *Exotic Sources of Power*.

Massachusetts Inst. of Tech.

Saugus Iron works—one of the first in operation in this Country—was the scene of MIT's Student Metallurgical Society meeting Feb. 27th. A total of 50 students, faculty members, wives, secretaries, and dates visited the work's blast furnace, workshops, and water wheel. The work's crucible furnace was used to cook their hamburgs and hot dogs; hot chocolate and hot toddies were served all round.

University of Nevada

The Crucible Club, student chapter of the AIME at Mackay School of Mines, University of Nevada, held an open house April 2nd. Theme of the event was non-metallics, stressing the geology, mining, and metallurgy of fluorspar. President of the student chapter is Richard A. Hughes.

Polytechnic Inst. of Brooklyn

Brooklyn Poly's AIME-ASM Student chapter started its program off with a bang Feb. 9th. A semester of planning and reorganization was rewarded by an enthusiastic turnout of 48 metallurgical engineering graduates and several members of the faculty to hear Ward Minkler of Titanium Metals Corp. of America talk on the *Future and Fabrication of Titanium*.

Mr. Minkler pointed up improved fabrication techniques recently employed on titanium aircraft components, including applications utilizing its favorable mechanical properties in the mid-elevated temperature range, while proving its corrosion resistance in various media. The relative abundance of titanium ores causes Mr. Minkler to predict its use as a fairly common structural engineering material in the future. Titanium's future application as skin material for Mach 3 aircraft was also predicted.

Advance programing calls for chapter meetings every other week, with invited speakers to address the group. Several special spot programs are also on the agenda, and three field trips are being planned.

Chapter officers, with terms expiring in May, are: Paul Lane, president; Arthur Fillipi, vice president; Gerald Kotler, recording secretary; Joel Hirschhorn, corresponding secretary; and Joseph Lanzafame, treasurer.

NEW STUDENT MEMBERS

Berlin Technical University
Winkler, Ernst W. S.

Carnegie Institute of Technology
Worzala, Frank J.

Drexel Institute of Technology
Collins, Henry E.

Harvard University
Doherty, Paul E.

Massachusetts Institute of Technology
Pepie, Myron P.

Missouri School of Mines
Arrieche, Simon
Elliott, Robert C.

Montana School of Mines
Cronin, William J.

Northwestern University
Dash, John

Pennsylvania State University
Roy, Robert J.

Stanford University
Elkins, Perry E.
Thompson, Ralph E.

University of Washington
Allen, Richard P.
Lee, John Y. S.
Nyman, David H.
Reynolds, Richard E.
Turbitt, Bruce R.

UEC PROGRESS REPORT

Pouring of concrete foundations was begun in February at the site of the new United Engineering Center on 1st Ave., between 47th and 48th Sts., New York City. Steel Construction will start this spring.

Solicitation of funds is continuing. Of industry's $5 million quota, all but $148,000 had been raised by March; $750,000 of members' quota of $3,787,000, remains to be raised. The AIChE is the only society that has attained its quota; the AIME has 74 pct of its goal. Of a total non-student membership of 33,378, slightly more than 6000 had made pledges as of Jan. 1st. Pledges are payable over a three-year period, and no immediate cash payment is required.

AROUND THE SECTIONS

St. Louis section heard a description of the equipment that will carry American astronauts into space, during its Feb. 2nd meeting. Richard A. Fitzgerald, McDonell Aircraft Corp. addressed his comments to an audience of 55. A film on the constructional features used in the capsule was also shown.

The Section's March 11th meeting was on the St. Louis University campus. Augustin Udias Vallina, S.J., addressed the gathering on *Structure of the Sierra Maestra in Cuba.*

Pittsburgh section's Institute of Metals Group heard a talk on *Lattice Spacing Relationships in Metals and Alloys* during its Feb. 18th meeting. Speaker of the evening was T. B. Massalski, Fellow Head of Metals Physics section, Mellon Institute. The dinner-meeting took place at Stouffer's Restaurant in Pittsburgh.

Southeast section held its first meeting of the year on Jan 27th at the Thomas Jefferson Hotel in Birmingham, Ala. The meeting was featured by the installation of new officers; they are: E. P. Reed, chairman; H. W. Kendall, first vice chairman; J. W. Nicol, second vice chairman; and L. S. Chabot, secretary-treasurer. Over 100 members also listened to Walter B. Jones, state geologist, speak on progress in the oil industry, as well as other mineral resources of the State.

Part of Southeast section's Jan. 27th huge turnout is pictured above.

Southern California section's Mar. 11th meeting was host to Roger Newman of Huges Products' Semiconductor div, Materials Research Laboratory. Dr. Newman addressed the dinner meeting on *Optical Properties of Some Transition Metal Monoxides.* Dr. Newman is head of the Physics Dept in the Materials Research Lab.

Oregon section watched a film entitled *The Allotropic Transformations of Cobalt and Cobalt-Nickel Alloys* during its Jan. 29th meeting. Providing commentary on the sound-color film was F. R. Morral, head of the cobalt information center at Battelle Memorial Institute.

Hudson-Mohawk section listened to R. S. Davis, Arthur D. Little, Inc., speak *On the Response of Solids to Intense Stress Waves* during its Jan. 14th meeting. The 40 persons in attendance also witnessed presentation of a membership pin to Walter Hibbard in recognition of his recruitment of five or more members. Section chairman A. A. Burr also encouraged members to support the United Engineering Center's building fund campaign.

Uranium Milling Papers At May Symposium

Uranium section will hold its Fifth Annual Uranium Symposium in Moab, Utah, May 6-8. A number of papers on uranium milling are scheduled, and a milling forum will be held the afternoon of Saturday, May 7th. Sunday, May 8th, will be devoted to field trips through the new carbonate circuit of the Uranium Reduction Co. mill in Moab.

A complete agenda of social events has also been set up. Among these are a welcoming luncheon, annual banquet, chuck-wagon dinner and *blow-out*, and boat trips down the Colorado river canyon.

For more details as they become available, contact: *Maurice H. Brady, Secretary, Uranium Section, Box 501, Moab, Utah.*

NECROLOGY

Date Elected	Name	Date of Death
1930	Anderson, Axel E.	Jan. 10, 1960
1954	Brown, Robert F.	Jan. 11, 1960
1897	Carpenter, Alvin B. (Legion of Honor)	Jan. 10, 1960
1917	Castle, S. N.	Feb. 10, 1959
1937	Christie, J. B.	Aug. 15, 1959
1937	Clemens, George L.	Nov. 17, 1959
1954	Daffin, Douglas E.	Nov. 16, 1959
1949	Lewis, E. G.	June 18, 1959
1936	Lipsey, G. C.	Jan. 14, 1960
1935	Mann, Homer A.	Jan. 13, 1960
1947	Meade, Ray	Unknown
1939	Mecia, Joseph A.	Jan. 13, 1960
1932	Miller, Jared H.	Jan. 16, 1960
1957	Nevels, Charles D.	Nov. 16, 1959
1955	Parrott, F. W.	Dec. 30, 1959
1954	Pinkney, H. D.	Jan. 19, 1960
1954	Redman, Kenneth G.	Oct. 23, 1959
1949	Sammons, Frederick C.	Jan. 17, 1960
1941	Tate, J. G.	Oct. 23, 1959

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Feb. 29, 1960, was 33,747; in addition 2,511 Student Members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Brytczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Alessi, Samuel P., Chicago, Ill.
Agarwal, Jagdish C., Monroeville, Pa.
Cleary, Thomas A., Jr., Youngstown, Ohio
Courtney, Arthur B., Nicaro, Oriente, Cuba
Garland, Acel, Cranford, N. J.
Goedecke, Siegfried, Hamburg, Germany
Griffin, John F., Jr., Canonsburg, Pa.
Griffin, Thomas G., Carnegie, Pa.
Holland, Wilson A., Knoxville, Tenn.
Kiser, James M., Homewood, Ill.
Kotyk, Michael, Monroeville, Pa.
Kowbuz, Miro F., Ajo, Ariz.
Loch, Luther D., Niagara Falls, N. Y.
Lyon, Lockwood, E. Chicago, Ind.
McCready, Haynes M., Pittsburgh, Pa.
Petrovich, Anton L., Chester, Pa.
Planje, Theodore J., Rolla, Mo.
Saddington, Robert R., Copper Cliff, Ontario, Canada
Smith, Eugene G., Long Beach, Calif.
Smith, John R., Babylon, N. Y.
Takamura, Jin-Ichi, Chicago, Ill.
Upritchard, William, Mineola, N. Y.
Vargo, Edward J., Cleveland, Ohio

Associate Members

Berezin, Isaac, Sao Paulo, Brazil
Contos, George, Woodside, N. Y.
Duncan, George V., New York, N. Y.
Eareckson, John L., Houston, Tex.
Hoyt, Charles R., Denver, Colo.
Otto, Arthur L., West Orange, N. J.
Simonton, Carl B., Youngstown, Ohio
Soutar, Douglas H., Greenwich, Conn.

Junior Members

Beattie, William G., Phillipsburg, N. J.
Bennett, William A., Hurley, N. Mex.
Bufferd, Allan S., Boston, Mass.
Cahn, John W., Schenectady, N. Y.
Gray, Robert G., Pittsburgh, Pa.
Klinefelter, Carl L., Milwaukee, Wisc.
Lippart, Thomas E., Dayton, Ohio
Lummp, Charles H., Jr., Whiting, Ind.
Millunzi, Andrew C., Pittsburgh, Pa.
Moberly, John W., Mountain View, Calif.
San Miguel, Alfredo F., Jr., Washington, D. C.
Thornton, Peter H., Philadelphia, Pa.
Uram, Stuart Z., Cambridge, Mass.

REINSTATEMENT

Member

Redelfs, Robert G., Monaca, Pa.

REINSTATEMENT—CHANGE OF STATUS

Junior to Member

Hopkins, William G., Pittsburgh, Pa.
Levinson, David W., Chicago, Ill.

Student to Junior

Fisher, Harvey, Bridgeport, Conn.

CHANGE OF STATUS

Associate to Member

Wang, Teh Po, Newark, N. J.

Junior to Member

Ieronimo, Samuel J., Neptune, N. J.
Trilli, Lawrence J., Hammond, Ind.

Student to Member

Brondyke, Kenneth J., New Kensington, Pa.

SPECIAL REINSTATEMENT

Associate Member

Clemm, Peter J., Schenectady, N. Y.

Junior Member

Cordier, J. A., Germain, France

BRADLEY STOUGHTON

An Appreciation
by Allison Butts

Bradley Stoughton died at his home in Bethlehem, Pa., on December 30, 1959, at the age of 86. He had appeared to be in good health, going to his office at Lehigh University a part of every day when in Bethlehem. He passed away in sleep. During the preceding day he had attended a meeting at the Lukens Steel Co. in Coatesville, of which he was a Director. His associates and all who knew him marvelled at his unusual activity and vigor, which were scarcely diminished until the last year or two of his life.

He was one of the oldest and most distinguished members of AIME, having been a member for 62 years. He was Secretary of the Institute from 1913 to 1921, chairman of the Iron and Steel Committee in 1922-1923, and was Howe Memorial Lecturer in 1927.

He was graduated from the Sheffield Scientific School of Yale University in the class of 1893 with the degree of Ph.B. He then went to Massachusetts Institute of Technology, receiving the degree of B.S. in 1896. Lehigh University awarded him the honorary degree of D.Eng. in 1943. He taught for a year at MIT after graduation and went to Columbia in 1897 as assistant to Henry Marion Howe. During the next four years he held successive positions with the Illinois Steel Co., American Steel and Wire Co., and Benjamin Atha and Co.

During his employment in the steel industry, he invented a side-blown converter for making steel castings and a process for oil melting in cupolas.

Returning to Columbia University in 1902, he taught six years in the School of Mines and became acting head of the department of metallurgy. After a few years in business as a consulting engineer, he was elected Secretary of AIME. In 1923 he went to Lehigh to head the department of metallurgy, retiring in 1939. From 1936 to 1939 he was Dean of Engineering at Lehigh.

Two world wars and an event of outstanding economic importance in the steel industry commanded the service of Professor Stoughton. He was a member of the National Council of Defense in 1918-1919, head of the metallurgical division and later vice chairman of the engineering division of the National Research Council, and a member of the welding committee of the Emergency Fleet Corp. In 1922 he made the field study and wrote the report used by President Harding in the campaign to secure the 8-hr day in the American steel industry. In 1941-1945 he was chief of the heat-treating equipment unit of the tools section, War Production Board, and was acting head of the foundry equipment section in 1944-1945. After the war he went to Europe as London representative of the Technical Industrial Intelligence Commission.

Service in professional engineering societies occupied a great deal of Bradley Stoughton's time. Nearly every one of which he became a member enlisted his talent for leadership in one way or another. He was President of the Yale Engineering Association during 1922-1924. He was chairman of the Electrothermic Division of the Electrochemical Society in 1922 and President of the Society in 1931. He was Treasurer of the American Society for Metals in 1938-1939 and President of the Society in 1941. He was President of the Engineers' Club of the Lehigh Valley in 1928-1929. He was a member also of the American Iron and Steel Institute, the British Iron and Steel Institute, the American Society for Testing Materials, the Canadian Institute of Mining and Metallurgy, the Society for Engineering Education, Sigma Xi, and other societies.

He was awarded the Grasselli medal by the Society of Chemical Industry in 1929. In 1943 the Lehigh Valley Chapter of the American Society for Metals established in his honor the annual Bradley Stoughton Award for outstanding contribution to metallurgy.

Professor Stoughton was author of **The Metallurgy of Iron and Steel,** published in 1908 and for about 40 years the leading American textbook on the subject. In 1926 he was co-author of **Engineering Metallurgy,** a pioneer textbook in its field. In 1933 he was co-author of **The Alloys of Iron and Silicon.**

It often happens that a feeling of high regard arises mutually between student and professor. With Bradley Stoughton it was much more than that. In many instances regard became a warm friendship which lasted through life. Keeping in touch with former students, and with a host of other friends as well, took the place of a hobby for him. He had none of the frequent hobbies, but he did enjoy people, and his work was always a source of real pleasure to him. Perhaps most of all he enjoyed helping others. Possessed of a keen sense of humor, he was always ready with a story or joke. But these were reserved for sociability; he took his teaching and other work most seriously.

OBITUARIES

Frederick C. Sammons, (associate member 1949) died at his Los Angeles home on Jan. 16th. At his death, Mr. Sammons was manager of West Coast operations for General Refractories Co., which he joined in 1943.

Coming Events

Apr. 3-8, Sixth Nuclear Engineering and Science Conference, Coliseum, New York.

Apr. 4-6, AIME 43rd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Palmer House, Chicago.

Apr. 19-22, International Symposium on the Metallurgy of Plutonium, sponsored by the Societe Francaise de Metallurgie and the French Atomic Energy Commission, Grenoble, France.

Apr. 20-22, Annual Meeting, AIME Acid Converter and Basic Oxygen Steel Committee, Ambassador Hotel, Los Angeles.

Apr. 21-22, AIME Southwest Metals and Minerals Conference, Ambassador Hotel, Los Angeles.

Apr. 23-27, Powder Metallurgy Show, sponsored by Metal Powder Industries Federation, Drake Hotel, Chicago.

Apr. 25-29, ASME, Metals Engineering Conference, Hotel Biltmore, Los Angeles.

Apr. 28-30, AIME-ASM Northwest Regional Conference, Sheraton Hotel, Portland, Ore.

May 2-5, The Electrochemical Society, Spring national meeting, LaSalle Hotel, Chicago.

May 4, Chicago section, NOHC, Spring Dinner Meeting, Phil Smidt's Restaurant, Hammond, Ind.

May 9-11, Society for Nondestructive Testing, Second Southwest Regional Convention, The Baker Hotel, Dallas.

May 9-13, American Foundrymen's Society, National Castings Congress and Exposition, Convention Hall, Philadelphia.

May 9-13, American Society for Metals, Southwestern Metal Exposition and Congress, State Fair Park, Dallas.

May 25-26, AIME Symposium on Refractory Metals and Alloys, McGregor Memorial Conference Center, Wayne State University, Detroit.

May 26-27, The Metallurgical Society, New England Regional Conference on *New Developments in Metalworking*, Statler-Hilton Hotel, Boston.

June 9-10, AIME Columbium Symposium, sponsored by the Hudson-Mohawk section, Hotel Sagamore, Lake George, N. Y.

June 13-15, First International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPIF.

June 20-24, American Society for Engineering Education, 68th annual convention, Purdue University, Lafayette, Ind.

June 26-July 1, American Society for Testing Materials, Annual Meeting and apparatus exhibit, Chalfonte-Haddon Hall, Atlantic City, N. J.

July 11-12, AIME Conference on the Response of Materials to High-Velocity Deformation, Estes Park, Colo.

Oct. 5-7, Rocky Mt. Minerals Conference, Newhouse Hotel, Salt Lake City.

Oct. 17-21, Fall Meeting of The Metallurgical Society of AIME, Sheraton Hotel, Philadelphia.

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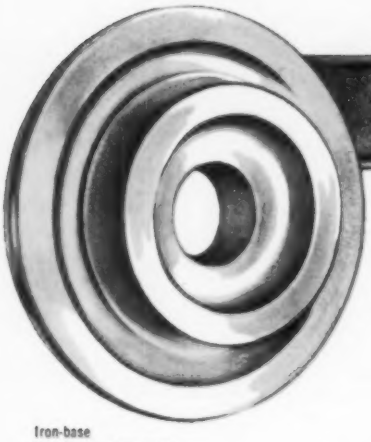

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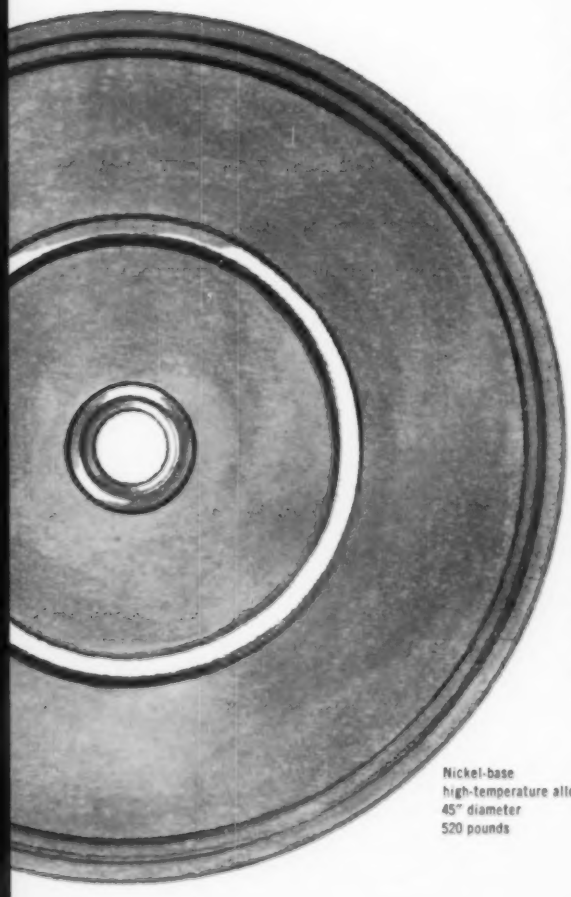

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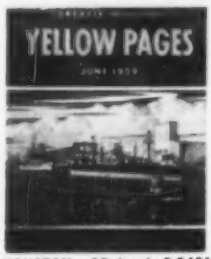

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